ROADS

1. INTRODUCTION

Rural roads play an important role in the overall development of rural areas as access to social and economic infrastructure and services are the sine qua non of rural development. In an indirect way, rural roads influence the process of growth through changes in socio-economic attitudes of people by facilitating the dissemination of knowledge and reduction of inequalities leading to better quality of life.

Rural roads are very essential to:

- promote and sustain agricultural growth
- improve basic health and hygiene
- provide access to schools and other educational opportunities
- provide access to economic opportunities
- create employment opportunities
- enhance democratic processes and bring people into national mainstream
- enhance local skills
- reduce vulnerability and poverty
- act as infrastructure multiplier

Rural Connectivity is perceived as one of the major components in increasing the agricultural output and earning capacity of the rural population. Improved rural connectivity will lead to marked improvement in the quality of life, by way of better educational facilities, improved health services, improved attendance of teachers as well as students etc. Accessibility also leads to improvement in governance and provision of other utility and emergency services.

1.1. IRC CLASSIFICATION OF ROADS

1) National Highways (NH)
2) State Highways (SH)
3) Major District Roads (MDR)
4) Other District Roads (ODR)
5) Village Roads (VR)

1.1.1. National Highways (NH)

The National Highways Network of India, is a network of highways that is managed and maintained by Government of India. These highways measure over 70,934 km (44,076 mi) as of 2010, including over 1,000 km (620 mi) of limited-access Expressways.

The National Highways Authority of India (NHAI) is the nodal agency responsible for building, upgrading and maintaining most of the national highways network. It operates under the Ministry of Road Transport and Highways. The NHAI often uses a public-private partnership model for highway development, maintenance and toll-collection.

National Highways plying through Tamil Nadu are listed below in the table:

S.No.	NH No.	Route	Length (km.)
1	**4**	From Andhra Pradesh Border - Thiruvalam - Walajepet - Kancheepuram - Sriperumbdur - Poonamallee - Chennai	123 km (76 mi)
2	**5**	From Andhra Pradesh Border - elaur - Gummidipundi – Kavarapettai - Chennai	45 km (28 mi)
3	**7**	From Karnataka Border - Hosur - Krishnagiri - Dharmapuri - Salem - Namakkal - Karur - Dindigul - Madurai - Virudunagar-Sattur - Kovilpatti - Tirunelveli - Nanguneri - Vattakottai up to Kanniya Kumari	627 km (390 mi)
4	**7A**	Palayan Kottai - Vagaikulam - Tuticorin	51 km (32 mi)
5	**47**	Salem - Erode - Coimbatore - Palakkad - Thrissur - Kochi - Kollam - Trivandrum - Nagercoil - Kanniya Kumari	363 km (226 mi)
6	**45**	Chennai - Tambaram - Chengalpattu - Madurantakam - Tindivanam - Viluppuram - Ulundurpettai - Trichy - Manapparai -Dindigul - Theni	550 km (340 mi)
7	**45A**	Villuppuram - Pondicherry - Cuddalore - Chidambaram - Karaikal - Nagappattinam	147 km (91 mi)
8	**45B**	Trichy - Viralimalai - Thuvarankurichchi - Melur - Madurai - Aruppukottai - Pandalgudi - Ettaiyapuram - Tuticorin	257 km (160 mi)
9	**45C**	Thanjavur - Kumbakonam - Sethiathope - Vadalur - Neyveli Township - Panruti and terminates near Vikravandi on NH-45.	159 km (99 mi)
10	**46**	Krishnagiri - Vaniyambadi - Vellore - Ranipet	132 km (82 mi)
11	**47**	It re-enters Tamil Nadu border at Kaliyakkavilai - Kuzhithurai - Marthandam - Thuckalay - Nagercoil - Suchindrum -Kanyakumari.	224 km (139 mi)
12	**47B**	The highway starting from the junction of NH 47 near Nagercoil connecting Aralvaymozhi and terminating at its junction with NH7 near Kavalkinaru	45 km (28 mi)

S.No.	NH No.	Route	Length (km.)
13	**49**	From Kerala Border - Bodinayakkanur - Teni - Usilampatti- Madurai - Manamadurai - Paramakkudi - Ramanathapuram - Mandapam - Rameswaram	290 km (180 mi)
14	**66**	Krishnagiri - Uthangarai - Chengam - Tiruvannamalai - Gingee - Tindivanam - Pondicherry	208 km (129 mi)
15	**67**	Nagappattinam - Thiruvarur - Thanjavur - Trichy- Karur - Kangeyam - Coimbatore - Ooty - Gudalur - Teppakadu up to Karnataka Border	505 km (314 mi)
16	**68**	Salem - Valapadi - Attur - Chinnasalem - Kallakkurichchi - Ulundurpettai	134 km (83 mi)
17	**205**	From Andhra Pradesh Border - Tiruttani - Tiruvallur - Ambathur - Chennai	82 km (51 mi)
18	**207**	Hosur up to Karnataka Border	20 km (12 mi)
19	**208**	From Kerala Border - Sengottai - Tenkasi - Sivagiri - Srivilliputtur - T.Kallupati - Thirumangalam	125 km (78 mi)
20	**209**	Dindigul - Palani - Udumalaippettai - Pollachi - Coimbatore - Annur - Satyamangalam - Hasanur up to Karnataka Border	286 km (178 mi)
21	**210**	Trichy - Pudukkottai - Tirumayam - Karaikkudi - Devakottai - Devipattinam - Ramanathapuram	160 km (99 mi)
22	**219**	From Andhra Pradesh Border - Krishnagiri	22 km (14 mi)
23	**220**	From Kerala Border - Gudalur - Cumbum - Uthamapalayam - Theni	55 km (34 mi)
24	**226**	Thanjavur - Gandharvakottai - Pudukkottai - Thirumayam - Kilasevalpatti - Tirupattur - Madagupatti - Sivaganga - Manamadurai	144 km (89 mi)
25	**227**	Trichy - Lalgudi - Kallakudi - Kizhapalur - Udaiarpalayam - Jayamkondam - Gangaikondacholapuram - Kattumannarkoil - Lalpet - Kumaratchi - Chidambaram	135 km (84 mi)
26	**234**	From Andhra Pradesh Border - Peranampattu - Gudiyatham - Katpadi - Vellore - Polur - Tiruvanamalai - Villupuram	234 km (145 mi)

1.1.2. State Highways (SH)

The state highways are the roads which link important cities, towns, district headquarters within the state and connecting them with national highways or highways of the neighbouring states. These highways provide connections to industries/places from key areas in the state making them more accessible. The State Highways are maintained by the State Government.

1.1.3. Major District Roads (MDR)

These are important roads within a district connecting areas of production with markets and connecting these with each other or with the State Highways & National Highways. It also connects Taluk headquarters and rural areas to District headquarters.

1.2. CLASSIFICATION OF RURAL ROADS

The rural roads are commonly classified as :

1. Other District Roads (ODR)
2. Village Roads (VR), which is further classified as
    - Panchayat Union roads
    - Panchayat roads

1.2.1. Other District Roads (ODR)

Other District roads are the roads serving rural areas and providing them with outlet to market centers, Taluk head quarters, block head quarters or major district roads, and would serve to connect villages with a population of 1000 and above or a cluster of villages. These roads are owned by Highways Department.

1.2.2. Village Roads (VR)

Village roads are roads connecting villages or cluster of villages with each other to the nearest road of a higher category. These roads are under the Control of Rural Development and Panchayat Raj Department.

Roads

Indian road network of 33 lakh Km is the second largest in the world and consists of :

Classification	Length(in Km)
Expressways	1000
National Highways	70,934
State Highways	1,31,899
Major District Roads	4,67,763
Rural and Other Roads	26,50,000

MATERIAL CHARACTERIZATION

2. MATERIAL CHARACTERIZATION

2.1. INTRODUCTION

The main constituents of a pavement structure comprise of soils, mineral aggregates, bituminous binders and stabilizers like lime, cement etc. Among these, mineral aggregates play the major role. All roads have to be formed on soil and are required to make optimum use of the locally available materials, if it is to be economical. The materials, which are of concern in the structural layers of the pavement, should be selected based on suitability, availability, economy and previous experience. This aspect must be considered at the design stage so that the materials which are the most economical and best suited to the prevailing conditions can be selected.

2.2. SOIL AS ROAD CONSTRUCTION MATERIAL

Soil is an accumulation or deposit of earthern material derived naturally from the disintegration of rocks or decay of vegetation. Subgrade soil is an integral part of the road pavement structure as it provides support to the pavement as its foundation. The main function of the subgrade is to give adequate support to the pavement and for this the subgrade should possess sufficient stability under adverse climatic and loading conditions. The formation of waves, corrugations, rutting and shoving in black top pavements are generally attributed to poor subgrade conditions. When soils used in embankment construction, in addition to stability, compressibility is also important as differential settlement may cause failure. Soil is used in its natural form (gravel & sand) or in a processed form (stabilized layer) for pavement construction. Soil is also used as a binder in water-bound macadam layers.

Soil is, therefore considered as one of the principal highway materials. The foundation of other cross-drainage structures (culverts, bridges and retaining walls) rests on soils and their stability depends on the soil strength. Knowledge of soil properties is necessary to select the embankment material, pavement structure, drainage system and foundation of structures. When a high embankment rests on soft ground, its stability can be predicted only by studying the properties of soil. Frost actions, common in high altitudes, can be taken care of if the soil properties are known. Soil consists mainly of mineral matter formed by the disintegration of rocks, by the action of water, frost, temperature, pressure or by plant or animal life. Based on the individual grain size of soil particles, soils have been classified as gravel, sand, silt and clay.

2.2.1. TYPES OF SOILS

Soils occur in a fairly wide variety in our country, as can be seen from the soil map of India. Some of the major types found in the country are:

Alluvial Soils : These are mostly found in the Indo-Gangetic plain. Generally, these are composed of sand, silt and clay and make fair to good subgrade material.

Fine Sand : It is confined mostly to desert areas in the north western part of the country. This soil lacks binder fraction and is not well graded.

Coastal Soils : The sands/sandy soils forming the coastal alluvium usually make good subgrades.

Black cotton Soils : Black cotton soils occur in parts of Madhya Pradesh, Maharashtra, Andhra Pradesh and Karnataka. These soils are characterized by pronounced volume changes (swelling upon wetting and shrinkage after drying) and low strengths at high moisture content.

Red Gravelly Soils : The moorums and red gravelly soils are found in various pockets and are generally less problematic.

2.2.2. INDIAN SOIL CLASSIFICATION SYSTEM

2.2.2.1. Major groups

All soils, as per the Indian Soil Classification System, are divided into three main groups:

(a) **Coarse-grained soils**, having more than half the total material by weight, larger than 75 micron sieve size.

(b) **Fine-grained soils**, having more than half the total material by weight smaller than 75 micron sieve size.

(c) **Highly organic soils**: these soils contain larger percentages of fibrous organic matter such as peat and particles of decomposed vegetation. In addition, certain soils containing shells, concretions, cinders and other non-soil materials in sufficient quantities are also included in this group.

Based on particle size, the soils can be classified as under, adopting the IS soil classification system:

The classification of soil as per IS nomenclature, the range of the maximum dry densities of these materials and their approximate CBR values are given in Table 2.1

Table 2.1 Classification of soils as per IS System

Soil Group Description	Symbol	Unit Dry Weight, gm/ cm^3	CBR %
Well graded gravels and gravel sand mixture (fines < 5%)	GW	2.00-2.24	60-90
Poorly graded gravel and gravel sand mixture (fines < 5%)	GP	1.76-2.24	25-60
Silty gravel and gravel sand mixture (fines > 12%)	GM	2.08-2.22	20-80
Clayey gravels and gravel sand silt mixtures (fines < 5%)	GC	1.92-2.24	20-80
Well graded sand and gravely (fines < 5%)	SW	1.76-2.08	20-60
Poorly graded sands and gravely sand (fines < 5%)	SP	1.59-1.92	10-30
Silty sand and sand-silt mixtures (fines > 12%)	SM	1.92-2.16	10-40
Clayey sands and sand-clay mixtures (fines >12%)	SC	1.68-2.08	15-50
Inorganic silt, very fine rock floor	ML	1.60-2.00	5-20
Clayey silt or fine sand, Inorganic clay, gravelly, sandy or silts	CL	1.60-2.00	5-15
Organic silt and silty clays	OL	1.44-1.60	3-8
Inorganic silt elastic and micaceous silts	MH	1.28-1.60	3-8
Inorganic fat clays	CH	1.44-1.76	3-5
Organic silt and clays	OH	1.28-1.68	2-4

Field Identification Procedures : Unified Soil Classification System

Field Identification Procedures (Excluding particles larger than 75µm and basing fractions on estimated weights)							Group Symbols	Typical Names	Information Required for Describing Soils
Coarse-grained soils More than half of material is larger than 75 µm sieve size	(The 75 sieve size is about the smallest particle visible to naked eye)	Gravels More than half of coarse fraction is larger than 4 mm sieve size.	Clean gravels (little or no fines)	Wide range in grain size and substantial amounts of all intermediate particle sizes			*GW*	Well graded gravels, gravel-sand mixtures, little or no fines	Give typical name; indicate approximate percentages of sand and gravel; maximum size; angularity, surface conditions, and hardness
				Predominantly one size or a range of sizes with some intermediate sizes missing			*GP*	Poorly graded gravels, gravel-sand mixtures, little or no fines	
			Gravels with fines (appreciable amount of fines	Non-plastic fines (for identification procedures, see ML below			*GM*	Silty gravels, poorly graded-sand-silt mixtures	
				Plastic fines (for identification procedures, see *CL* below)			*GC*	Clayey gravels, poorly graded gravel-sand-clay mixtures	For undisturbed soils add information on stratification, degree of compactness, cementation, moisture conditions and drainage characteristics. Example: *Silty sand*, gravely; about 20% hard, angular gravel particles 12 mm maximum size; rounded and subangular sand grains coarse to fine, about 15% non-plastic fines with low dry strength; well compacted and moist in place; alluvial sand; *(SM).*
		Sands More than half of coarse fraction is smaller	Clean gravels (little or no fines)	Wide range in grain sizes and substantial amounts of all intermediate particle sizes.			*SW*	Well graded sands, gravely sands, little or no fines	
				Predominantly one size or range			*SP*	Poorly graded sands, gravely sands, little or no fines	
			Gravels with fines (appre-ciable amount	Non-plastic fines (for identification procedures, see *ML* below)			*SM*	Silty sands, poorly graded sand-silt mixtures	
				Plastic fines (for identification procedures, see CL below)			*SC*	Clayey sands, poorly graded sand-clay mixtures	
Fine-grained soils More than half of material is smaller than 75 µm sieve size.		Silts and clays liquid limit less than 50		Dry Strength (crushing characteristics)	Dilatancy (reaction to shaking)	Toughness (consistency near plastic limit)			
				None to slight	Quick to slow	None	*ML*	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands with slight plasticity.	Give typical name; indicate degree and character of plasticity, amount and maximum size of coarse grains; colour in wet condition, odour if any, local or geologic name, and other pertinent descriptive information, and symbol in parentheses.
				Medium to high	None to very Slow	Medium	*CL*	Inorganic clays of low to medium plasticity, gravely clays, sandy clays, silty clays, lean clays.	
				Slight to medium	Slow	Slight	*OL*	Organic silts and organic lilt-clays of low plasticity.	For undistributed soils add information on structure, stratification, consistency in undisturbed and remoulded states, moisture and drainage conditions
		Silts and clays liquid limit greater than 50		Slight to medium	Slow to none	Slight to medium	*MH*	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts.	
				High to very high	None	High	*CH*	Inorganic clays of high plasticity, fat clays.	Example: *Clayey silt*, brown; slightly plastic; small percentage of fine sand; numerous vertical root holes; firm and dry in place; loess; *(ML)*
				Medium to high	None to very slow	Slight to medium	*OH*	Organic clays of medium to high plasticity.	
Highly Organic Soils				Readily identified by colour, odour, spongy feel and frequently by fibrous texture.			*Pt*	Peat and other highly organic soils	

Based on particle size, the soils can be classified as under, adopting the IS soil classification system:

Unified Soil Classification System

Description			Group Symbols	Laboratory Criteria: Fines (%)	Grading	Plasticity	Notes
Coarse grained (more than 50% larger than 63 mm BS or No. 200 US sieve size)	Gravels (more than 50% of coarse fraction of gravel size)	Well graded gravels, with little or no fines	GW	0-5	$C_u>4$ $1<C_c<3$		Dual symbols if 5-12% fines. Dual symbols if above A-line and 4< PI<7
		Poorly graded gravels, sandy gravels, with little or no fines	GP	0-5	Not satisfying GW requirements		
		Silty gravels, silty sandy gravels	GM	>12		Below A-line or PI<4	
		Clayey gravels, clayey sandy gravels	GC	>12		Above A-line and PI>7	
	Sands (more than 50% of coarse fraction of sand size)	Well graded sands, gravelly sands, with little or no fines	SW	0-5	$C_u>6$ $1<C_c<3$		
		Poorly graded sands, gravelly sands, with little or no fines	SP	0-5	Not satisfying SW requirements		
		Silty sands	SM	>12		Below A-line or PI<4	
		Clayey Sands	SC	>12		Above A-line and PI>7	

The broad classification of soils (as per IS) into Gravels, Sands, Silts and Clays based on particle size is as under:

CLAY	SILT	SAND: Fine Sand	SAND: Medium Sand	SAND: Coarse Sand	GRAVEL

0.002mm (2 micron) | 0.075mm (75 micron) | 0.425mm (425 micron) | 2.0 mm | 4.75 mm

2.2.3. Symbols adopted as per Indian Soil Classification System:

First Alphabets	*Second Alphabets*
G: Gravel	W: Well graded
S: Sand	P: Poorly graded
M: Slit	L: Low plasticity
C: Clay	I: Intermediate plasticity
O: Organic soil	H: High plasticity

The first alphabet indicates the predominant soil type while the second alphabet denotes the basic engineering property of that soil type.

By way of examples, GW stands for well-graded gravel; SP for poorly-graded sand; ML for silt with low plasticity; CH for clay with high plasticity; GC for clayey gravel; SM for silty sand and so on. The plasticity chart for laboratory classification of fine-grained soils is given in Fig. 2.1

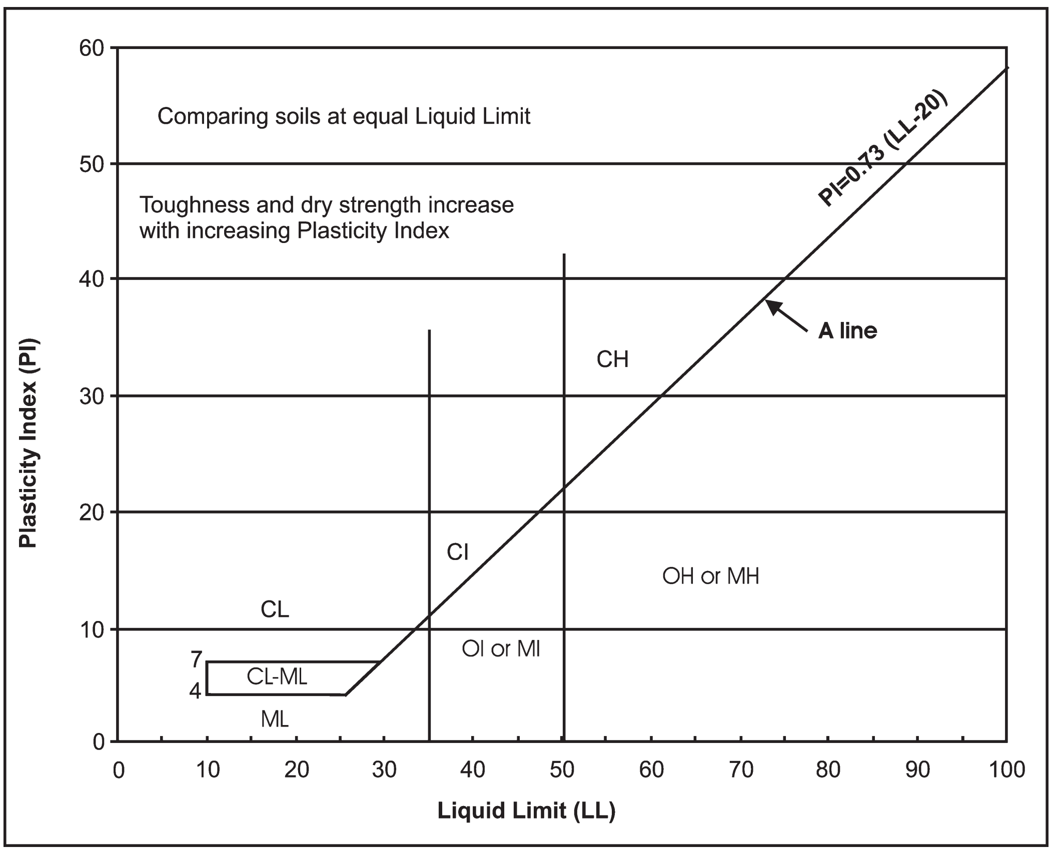
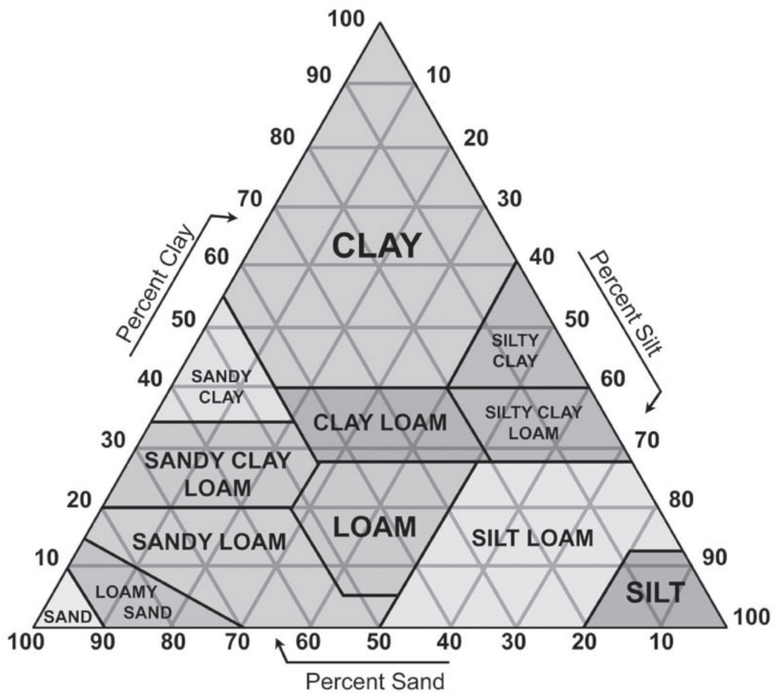


Fig. 2.1. Plasticity Chart for Laboratory Classification of Fine-grained Soils (IS : 1498 - 1970 Page No. 12)



Textural classification of soil

2.2.4. FIELD IDENTIFICATION PROCEDURE

As an aid to identify the broad soil types in the field without any laboratory testing, a visual classification is recommended. For visual classification, the following categories of soils are proposed:

Gravels : These are coarse materials with particle size over 4.75 mm. These may have little or no fines contributing to cohesion of the material.

Moorums : These are distinctly different materials from gravels and are products of decomposition and weathering of the parent rock. The properties of these materials naturally depend on the parent rock and the process of weathering and decomposition. Visually they look like gravels except for the difference that the percent fines is relatively much higher.

Sands : These vary in texture from coarse to fine but exhibit no cohesion. They allow water to permeate readily through them.

Silts : These are finer than sands in texture; lighter in colour compared to clays and exhibit little cohesion. Dilatancy is a specific property of silts. When a lump of silty soil mixed with water is alternately squeezed and tapped, a shiny surface makes its appearance.

Clays : These are finer than silts and are the ultimate product of weathering and decomposition of parent rock. Clay and clayey soils exhibit stickiness, high strength when dry and show no dilatancy. Black cotton soils and other expansive types of clays exhibit swelling and shrinkage and are characterized by a typical shrinkage pattern. A paste of clay with water when rubbed in between fingers leaves a stain which is not observed for silts.

2.2.5. LOW GRADE MATERIALS

This materials are available in abundant in our country which can be effectively used in road construction particularly for sub base/base courses and for shoulders. Some of the classifications of these materials are:

a) Moorum

b) Kankar

c) Dhandia

d) Laterite

e) Soft-stone/Sand stone

2.2.6. STABILIZED SOILS

Sometimes soil/soil-gravel/aggregates and waste materials such as fly ash, iron and steel slag and other such materials, available in the near vicinity of the construction sites do not conform to the grading, PI and strength requirements. Such inferior materials can be improved by adopting soil stabilization technique. The methods of stabilization can be broadly grouped as:

1. Mechanical Stabilisation
2. Lime Stabilasation
3. Cement Stabilisation
4. Lime-flyash stabilisation
5. Bitumen stabilisation
6. Two-stage stabilisation

The Mechanism of soil stabilization is described in section 3.2 of Chapter 6

The desirable properties of soil are :

i) Stability
ii) Incompressibility
iii) Permanency of Strength
iv) Minimum changes in volume
v) Good drainage
vi) Ease of Compaction

2.2.7. Soil and Material Survey:

The needed quantities of samples to be collected will depend upon the types of tests to be conducted and will vary from about 2 kg to 20 kg. For visual classification, gradation and simple plasticity tests, a small quantity (2-5 kg) will generally be enough while for detailed strength tests like the CBR etc. as much as 20 kg will be required.

2.2.7.1. Survey for materials and aggregates:

The locally available materials that can be incorporated in pavement design should be thoroughly and judiciously explored. The various types of soils encountered; sands from streams/river beds and other sources; moorum which may even be available at shallow depths below the ground level or laterite, kankar, dhandla, river sand-gravel mixes, etc. may be included. The locations of the PWD/Zilla Parishad

approved quarries for stone metal can be obtained from the district headquarters, the quarries for locally available materials like the ones listed above are generally not known but local enquiries from villagers, etc. can help a great deal in this regard. Samples of other locally available materials like lime, that could possibly be used as soil stabilizer should also be collected. Special care has to be exercised in collection of samples of these locally available materials since these are generally variable in their engineering properties. The locally available moorums and gravels from the same source can give widely different strength which will have significant implications in the construction and performance of roads. The site quality control of materials can be exercised meaningfully only if sampling and testing of these locally available materials has been carefully done and the design values arrived at judiciously based on the laboratory strength values.

2.2.7.2. FIELD SOIL SURVEY PROCEDURE

For roads, a single line of borings along the centre line, wherever there is a visible change in soil type shall be done and if same soil conditions prevail, 3 borings per kilometer length are sufficient.

Test pits 1m x 1m may be taken to a depth upto 1.5m.

For high embankments, If there is a soft underlying material, boring shall be taken to a depth of about twice the height of the embankment. The depth of ground water table and its fluctuations should be noted. The change in vegetation is indicative of subsoil conditions. Samples to be collected for classification tests from each boring Location and depth of strata to be tagged on to the sample bag.

For each soil type, a 20 kg sample will be required for compaction and strength (CBR) tests.

2.2.8. LABORATORY SOIL CLASSIFICATION TESTS

There are basically three laboratory tests required to be carried out for purposes of classifying a given soil sample. These are: (i) Wet Sieve Analysis (except in cohesionless material) carried out through a standard set of sieves as per IS: 2720 Part 4. (ii) Liquid limit test carried out on the fraction of soil passing 425 micron sieve, as per IS: 2720 Part 5. (iii) Plastic limit test carried out on the fraction of soil passing 425 micron sieve, as per IS: 2720 Part 5.

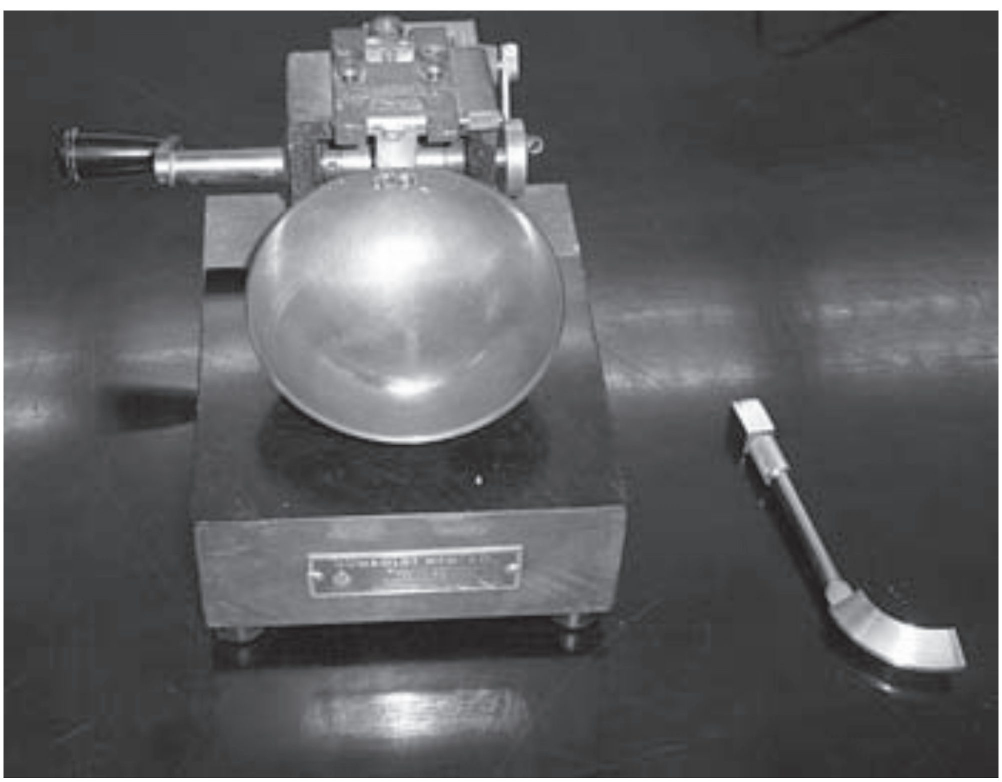
The definitions of Liquid Limit, Plastic Limit, Shrinkage Limit and Plasticity Index are given below.

Liquid Limit (LL) is the minimum water content (w1) at which the soil can flow under its own weight (has no strength). is defined as the moisture content at which 25 blows (taps) in the standardized liquid limit determination device (casagrande apparatus), will just close a specific groove in a sample of soil. Another common method for its determination is the cone penetrometer test method.

Plastic Limit (PL) is the minimum water content (wp) at which the soil can be rolled into a thread 3 mm in diameter, without breaking.

Shrinkage Limit (SL) is the water content at which further loss of moisture does not cause a decrease in the volume of the soil.

Plasticity Index (PI or Ip) is defined as the water content range over which a soil exhibits plastic behavior. It is the difference between the Liquid and Plastic Limits of a soil. PI = LL-PL; Ip = w1-wp . Since many properties of clays and silts such as their dry strength, compressibility, consistency near the Plastic Limit etc can be correlated with the Liquid and Plastic limits (Atterberg Limits), a Plasticity Chart was developed. Fig 1 (Page 12) shows the Plasticity Chart being used in the Indian Soil Classification System. All points representing inorganic clays lie above the "A" Line and all points for inorganic silts lie below it. This chart is extensively used for the classification of fine grained soils.



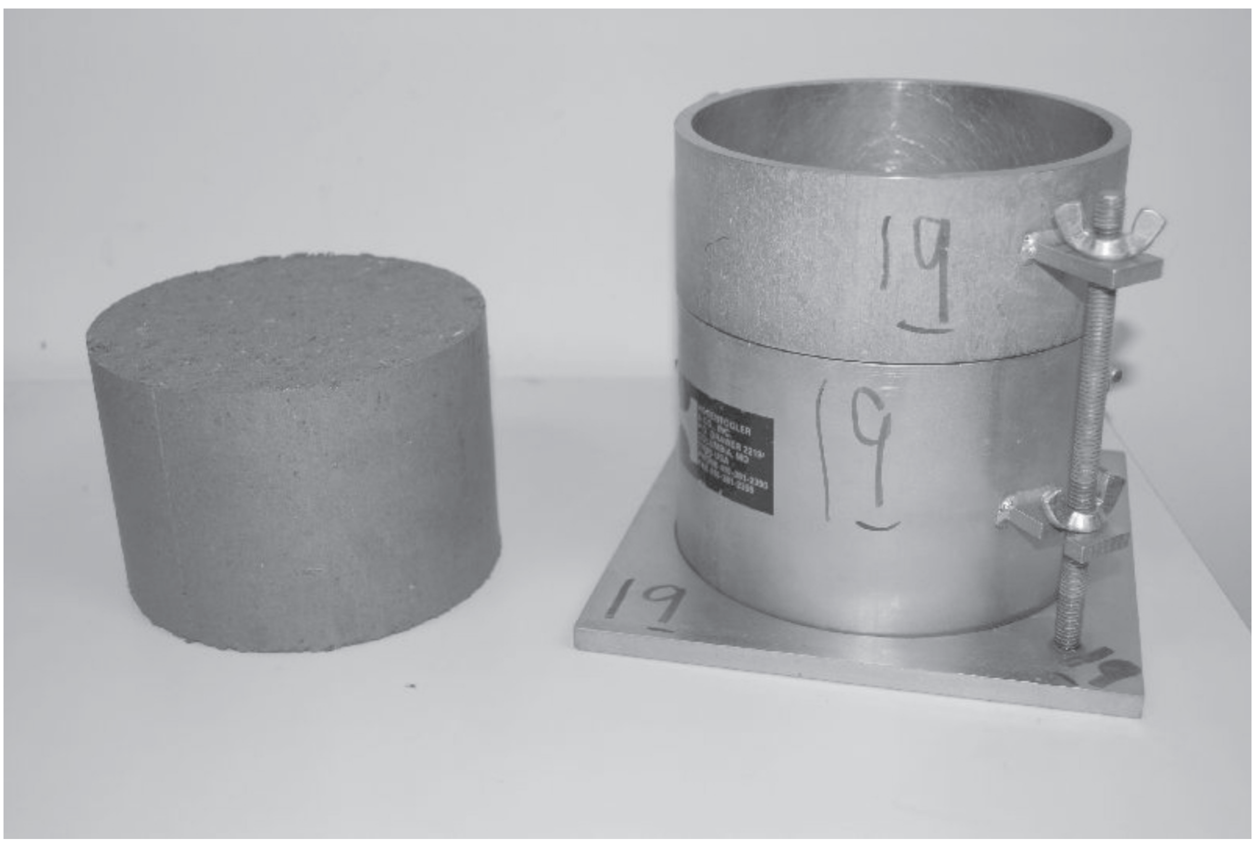
2.2.9. SOIL INVESTIGATIONS FOR EMBANKMENT AND SUBGRADE CONSTRUCTION

Prior to the construction of an embankment and subgrade, it is necessary to determine whether a given type of soil is suitable for use in embankment layers and in the subgrade. Also, for purposes of flexible pavement design, it is necessary to evaluate the subgrade soil properties and subgrade strength (CBR) after the subgrade soil has been compacted to the specified density. For the construction of low embankments (height less than 3 m), the following laboratory tests need to be carried out on representative samples of fill material:

Wet sieve analysis (except on cohesionless material) as pet IS: 2720 Part 4.

Liquid and Plastic Limit Tests on the fraction of soil passing 425 micron sieve, as per IS: 2720 Part 5.

Standard Proctor Compaction Test (Light Compaction) as per IS: 2720 Part 7 for the determination of Maximum Dry Density (MDD) and Optimum Moisture Content (OMC)



Standard Proctor Compaction Test Apparatus

In order to determine the suitability of an embankment fill material, it must be ensured that the material does not fall into any of the following categories considered "unsuitable" for use in embankment and subgrade construction:-

- Materials from swamps, marshes and bogs
- Peat, log, stump and perishable material, any soil that is classified as OL, OI, OH in accordance with IS:1498-1970.
- Materials susceptible to spontaneous combustion
- Materials with salts resulting in leaching in the embankment.
- Clay having liquid limit exceeding 70 and Plasticity Index (PI) exceeding 45.
- Expansive clays, 'Free Swelling Index' exceeding 50% when tested as per IS: 2720 (Part 40) - 1977, shall not be used as fill material.
- Materials in a frozen condition
- Materials with sulphate content (expressed as SO3) exceeding 0.5 percent by mass, when tested accordance with BS:1377-1975 test 9, shall not be deposited within 500 mm from concrete surface.

It must be ensured that the best available homogeneous soil is reserved for use in the subgrade (i.e, top 300 mm portion of the embankment) and that for use in the subgrade, the soil must have the maximum dry density not less than 16.5 KN/m^3 when tested as per IS:2720 Part 7. For high embankments (height more than 3 m), in addition to the tests mentioned above, it is necessary to obtain shear strength parameters, unit weight and moisture conditions to check stability against slip failures. Where soft material is encountered beneath the embankment, checking against excessive settlement is necessary for which consolidation properties are important. For cut sections, in addition to the three tests mentioned above, field density and moisture content determination are necessary. Typical Dry Density-Moisture Content Relationship is shown in Fig. 2.2

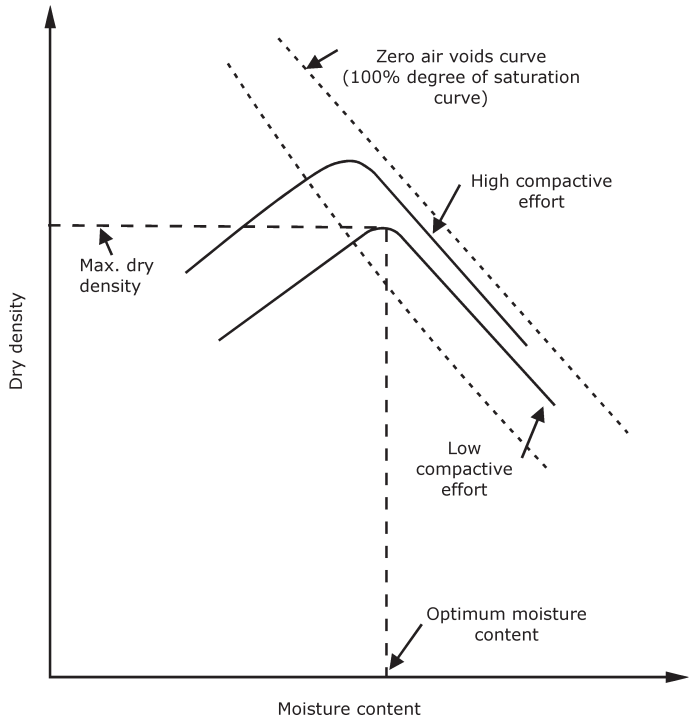
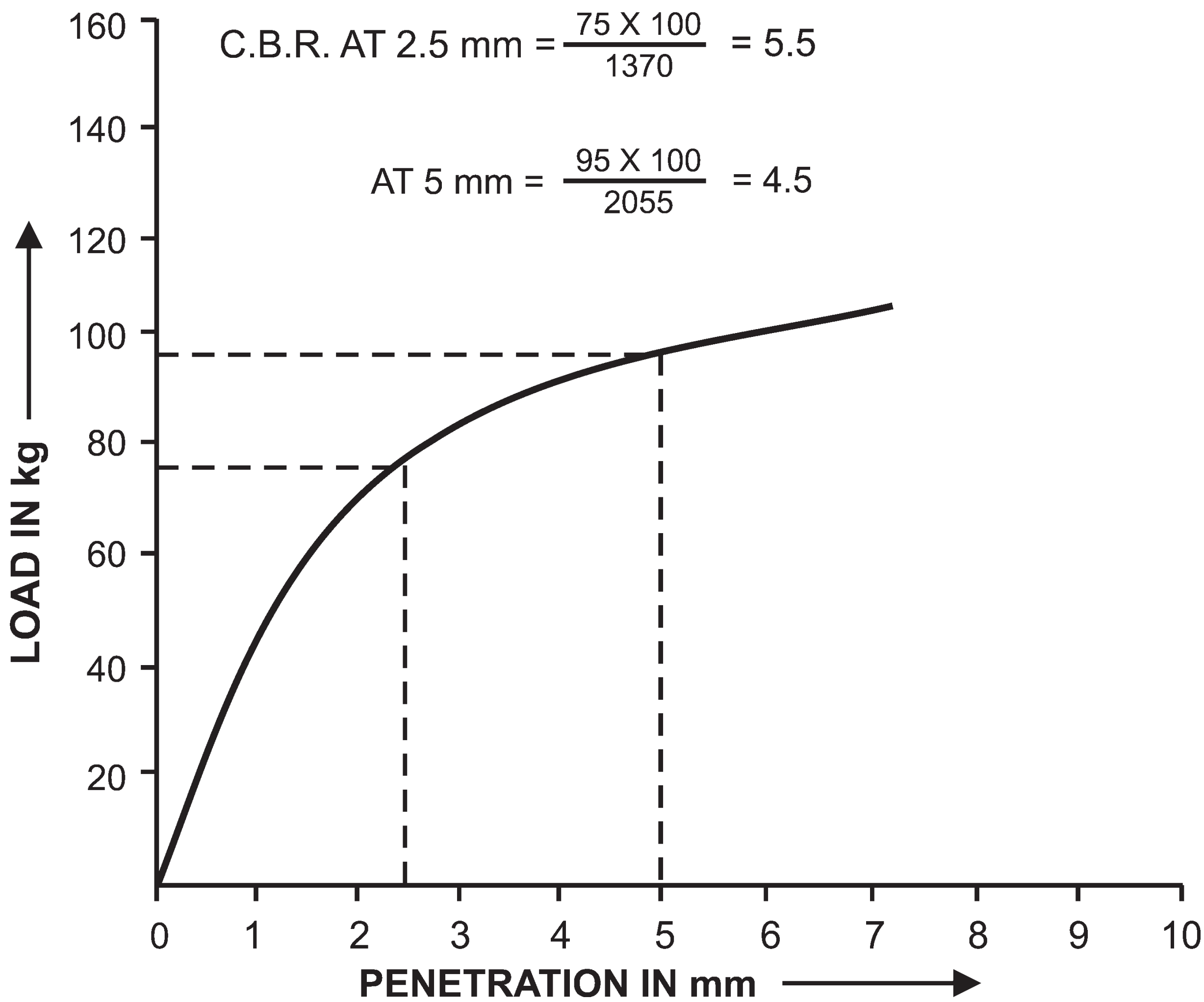


Fig. 2.2 Typical Dry Density-Moisture Content Relationship

The soil investigations for subgrade construction include wet sieve analysis, liquid and plastic limit tests, Standard Proctor Compaction test and the California Bearing Ratio test (Fig. 3). The CBR test carried out as per IS: 2720 Part 16 should be done on the sample compacted to the specified density and soaked under water for 4 days prior to testing. The frequency of CBR tests should normally be such that roughly one set of results (3 samples) are available for every km section of the road. For new roads, the CBR test should be carried out on samples prepared at optimum moisture content, compacted to the specified density corresponding to standard Proctor compaction test (IS:2720 Part 7), soaked under water for 4 days prior to testing. In case of existing roads requiring strengthening and also for roads in cutting, soil should be moulded at the existing in-situ density and soaked under water for 4 days prior to testing.



2.3. ROAD AGGREGATES

Aggregates form the major portion of pavement structure and they are the most voluminous ingredients used in pavement construction. Aggregates have to bear the stresses due to the wheel loads on the pavement and on the surface course. They also have to resist wear due to abrasive action of traffic. Most of the road aggregates are obtained from natural rocks. The conventional road aggregates in India are obtained by crushing of rocks. There are three main groups of rocks: Igneous, Sedimentary and Metamorphic. Within these three broad geological classes, there are hundreds of different types of rocks. Many of these rocks differ little from each other with regard to their road making qualities.

2.3.1. PROPERTIES OF ROAD AGGREGATES

Strength : The aggregates to be used in road construction should be sufficiently strong to withstand the stresses due to traffic wheel loads; hence they should possess sufficient strength to resist crushing.

Hardness : The aggregates used in the wearing course are subjected to constant rubbing or abrasion due to moving traffic. They should be hard enough to resist wear due to abrasive action of traffic.

Toughness : Aggregates in the pavements are also subjected to impact due to moving wheel loads. The resistance to impact or toughness is hence another desirable property of aggregates.

Durability : The stones used in pavement construction should be durable and should resist disintegration due to action of weather. The property of stones to withstand the adverse action of weather is called soundness.

Shape of the aggregates Aggregates, which happen to fall in a particular size range, may have rounded cubical, angular, flaky or elongated shape of particles. It is evident that the elongated or flaky particulates will have less strength and durability when compared with cubical, angular or rounded particles of same stone. Hence too flaky and too much elongated particles should be avoided as far as possible.

Adhesion : The aggregates used in bituminous pavement should have less affinity to water.

Table 2.2 : Requirements of Aggregates for Sub-Base, Base Course and Bituminous Surfacing Layers

Layer	Test	Test Method	Requirement (Percent. Max.)
Sub-base course	Aggregate Impact value	IS: 2386 (Part 4) - 1963	50
	Flakiness Index	IS: 2386 (Part 1) -1963	40
	Moisture or water absorption	IS: 2386 (Part 3) -1963	6
Base course	Aggregate Impact value	IS: 2386 (Part 4) -1963	40
	Flakiness Index	IS: 2386 (Part 1) -1963	30
	Moisture or water absorption	IS: 2386 (Part 3) -1963	3
Bituminous Surfacing	Los Angeles Abrasion value	IS: 2386 (Part 4) -1963	40
	Aggregate Impact value	IS: 2386 (Part 4) -1963	30
	Combined Flakiness and Elongation Index	IS: 2386 (Part 1) -1963	35
	Stripping value	IS: 6241- 1971	15
	Soundness Loss with Sodium Sulphate (5 cycles) Loss with Magnesium Sulphate (5 cycles)	IS: 2386 (Part 5) – 1963	12 18
	Water absorption	IS: 2386 (Part 3) – 1963	02

2.4. BITUMINOUS MATERIALS

Bitumen is defined as "A viscous liquid, or a solid, consisting essentially of hydrocarbons and their derivatives, which is soluble in trichloro- ethyelene and is substantially nonvolatile and softens gradually when heated. It is black or brown in colour & posseses waterproofing and adhesive properties. It is obtained by refinery processes from petroleum, and is also found as a natural deposit or as a component of naturally occurring asphalt, in which it is associated with mineral matter.

2.4.1. CLASSIFICATION OF BITUMINOUS BINDER

Bitumen or bituminous binder available in India is mainly of the following types:

Penetration Grade :

Bitumen 80/100:

The characteristics of this grade confirm to that of S 90 grade of IS-73-1992. This is the softest of all grades available in India. This is suitable for low volume roads and is still widely used in the country.

Bitumen 60/70:

This grade is harder than 80/100 and can withstand higher traffic loads. The characteristics of this grade confirm to that of S 65 grade of IS- 73-1992. It is presently used mainly in construction of National Highways & State Highways.

Bitumen 30/40:

This is the hardest of all the grades and can withstand very heavy traffic loads. The characteristics of this grade confirm to that of S 35 grade of IS-73-1992. Bitumen 30/40 is used in specialized applications like airport runways and also in very heavy traffic volume roads in coastal cities in the country.

Viscosity grade Bitumen:

The new method of grading the product has now rested on the viscosity of the Bitumen (at 60^0C and 135 ^{0}C). IS 73:2006 has been released by Bureau of Indian Standards. Three grades of Bitumen confirming to IS 73: 1992 are manufactured in India. **In this third revision grading of Bitumen is changed from penetration grade to viscosity grade.** To improve the quality of Bitumen, BIS revised IS-73-1992 Specifications based on viscosity grade (viscosity @ 60 deg. C) in July 2006. As per the Specifications, there are four grades VG-10, VG-20, VG-30 & VG-40.

The new grades have thus evolved with nomenclature:

Grades	Minimum of Absolute viscosity, Poise@ 600C	Approximate penetration grade
VG 10	800	80-100
VG 20	1600	———
VG 30	2400	60-70
VG 40	3200	30-40/40-50

Cutback Bitumen

Cutback is a free flowing liquid at normal temperatures and is obtained by fluxing bitumen with suitable solvents. The viscosity of bitumen is reduced substantially by adding kerosene or any other solvent. Cutback has been used in tack coat applications. Cut-back bitumen is used for cold weather bituminous road construction and maintenance. The petroleum distillates used for preparing cut-back bitumens are naphtha, kerosene, diesel oil, furnace oil or heavy distillate. There are different types of cut-back bitumen like the Rapid Curing (RC), Medium Curing (MC) and Slow Curing (SC). Rapid curing cut-back bitumen is recommended for the surface dressing in cold weather and patch repair work. Medium curing cut-back bitumen is in premix with less quantity of fine aggregate. Slow curing cut-back bitumen is used in premix containing appreciable quantity of fine aggregates. The classification of cut-back bitumen is given in Table 2.3

Table 2.3 : Classification of Cut-Back Bitumen

S.No	Type of Cut-back Bitumen	Penetration of Base Bitumen	Type of petroleum distillate	Amount of Distillate percent by volume of cut-back bitumen	Viscosity range of cut-back bitumen, cst
1	Rapid Curing (RC)	80/100	Naphtha	15-45	70-6000
2	Medium Curing(MC)	80/100	Kerosene	15-45	30-6000
3	Slow Curing (SC)	80/100	Heavy Distillate	0-50	70-6000
4	Bituminous Primer	80/100	Diesel oil	50-70	15-400

Modified Bitumen

Modified Bitumen are bitumen with additives. These additives help in further enhancing the properties of bituminous pavements. Pavements constructed with Modified Bitumen last longer which automatically translates into reduced overlays. Pavements constructed with Modified Bitumens can be economical if the overall lifecycle cost of the pavement is taken into consideration.

Bitumen Emulsion

Bitumen emulsion is a free flowing liquid at ambient temperatures. Bitumen emulsion is a stable dispersion of fine globules of bitumen in continuous water phase. Dispersion is obtained by processing bitumen and water under controlled conditions through a colloidal mill together with selected additives. The use of proper quality emulsifiers is essential to ensure that the emulsion has stability over time and also that it breaks and sets when applied on aggregates/road surface. It is chocolate brown free flowing liquid at room temperature. Bitumen Emulsions can be of two types cationic & anionic. Anionic bitumen emulsions are generally not used in road construction as generally siliceous aggregate is used in road construction. Anionic bitumen emulsions do not give good performance with siliceous whereas cationic bitumen emulsions give good performance with these aggregates. Therefore, cationic bitumen emulsions are far more popular than anionic bitumen emulsions.

Three types of bituminous emulsions are available,

1. Rapid Setting (RS)
2. Medium Setting (MS)
3. Slow Setting (SS)

If the bitumen emulsion is intended to break rapidly, the emulsion is said to possess rapid set quality. Emulsions, which do not break spontaneously on contact with stone, but break during mixing are medium set grades. When special types of emulsifying agents are used to make the emulsion relatively stable, they are called slow setting. The viscosity values of bitumen emulsions when tested using Sabolt Viscometer are given in Table. 2.4

Table 2.4 : Viscosity (in Secs) of Bituminous Emulsions (IS: 8887-1995)

Temperature	Type of Emulsion		
	RS	MS	SS
At 25ºC	-	-	20-100
At 50ºC	50-400	50-400	-

2.5. CEMENT AND CONCRETE

Cement is a material obtained by pulverizing clinker formed by calcining raw materials, primarily consisting of argillaceous materials. The argillaceous materials used are shale or clay. The calcareous material commonly used is limestone. These materials supply the essential components such as lime (CaO), Silica (SiO2).Alumina (Al2 O3) and iron oxide (Fe2O3). Cement, when mixed with water, forms a paste, which hardens and binds the particles of aggregates together, to form a hard durable mass called concrete. Ordinary cement is called Portland cement because of the resemblance of set cement to rock found on the English island of Portland. Cement shall be stored in a dry place and subjected acceptance tests prior to its immediate use. Before using any cement it would be advisable to get the cement tested for the following material properties to determine whether these properties meet the requirements as per IS standards.

- Fineness
- Setting time
- Soundness
- Compressive strength

2.5.1. TYPES OF CEMENT

BIS has classified Ordinary Portland Cement (OPC) into three grades. Grade of cement refers to the 28 days compressive strength in MPa. The classifications of cement are:

2.5.1.1. Ordinary Portland Cement (OPC) Grade33

1. Compressive strength of cement sand mortar (IS: 269-1989) not less than

   72 (+ or -) 1hours = 16MPa

   168 (+ or -) 2hours = 22MPa

   672 (+ or -) 4hours = 33MPa

2. Insoluble residue not more than 4%

3. MgO not more than 6%

4. SO_3 not more than 2.5 if C_3A up to 5%

5. SO_3 not more than 3.0 if C_3A greater than 5%

6. Loss on Ignition not more than 5%

7. Fineness (sq cm/g) not less than 2250

2.5.1.2. Ordinary Portland Cement (OPC) Grade 43

1.Compressive strength of cement sand mortar (IS: 8112-1989) not less than

72 (+ or -) 1hours = 23MPa

168 (+ or -) 2hours = 33MPa

672 (+ or -) 4hours = 43MPa

2. Insoluble residue not more than 2%

3. MgO not more than 6%

4. SO_3 not more than 2.5 if C_3A up to 5%

5. SO_3 not more than 3.0 if C_3A greater than 5%

6. Loss on Ignition not more than 5%

7. Fineness (Sqcm/g) not less than 2250

2.5.1.3. Ordinary Portland Cement (OPC) Grade 53

1. Compressive strength of cement sand mortar (IS: 12269-1987) not less than
   72 +/- 1hours = 27Mpa
   168 +/- 2hours = 37Mpa
   672 +/- 4hours = 53Mpa
2. Insoluble residue not more than 2%
3. MgO not more than 6%
4. SO_3 not more than 2.5 if C_3A up to 5%
5. SO_3 not more than 3.0 if C_3A greater than 5%
6. Loss on Ignition not more than 5%
7. Fineness (Sqcm/g) not less than 2250

2.5.1.4. Portland Pozzolana Cement (PPC) Grade-1 (Fly ash based)

This cement may be used in construction of base or sub base under flexible or rigid pavement. This type of cement is preferable to use in mass concrete works and under coastal environment for longer life of the pavement. The specification of the cement is given below.

1. Compressive strength of cement sand mortar (IS: 1489-1991) not less than
   168 (+ or -) 2hours = 22MPa
   672 (+ or -) 4hours = 33MPa
2. Insoluble residue not more than X+4*(100-X)/X% where X is % of pozzolana
3. MgO not more than 6%
4. SO_3 not more than 2.5 if C_3A up to 7%
5. SO_3 not more than 3.0 if C_3A greater than 7%
6. Loss on Ignition not more than 5%
7. Fineness (Sqcm/g) not less than 3000
8. Fly ash/Calcined clay 10-25 %

2.5.1.5. Blast Furnace slag cement

This cement is used in concrete works in coastal environment

- Compressive strength of cement sand mortar (IS: 455-1989) not less than
    - 72 1hours = 15.7MPa
    - 168 2hours = 21.6MPa
    - Loss on Ignition not more than 5%
- Fineness (Sqcm/g) not less than 2250
- Slag (Ground granulated slag) 25-65%

2.5.2. MATERIALS FOR CONCRETE

a) **Aggregates:** Cement concrete in pavements is subjected to high flexural stresses and abrasion. The aggregates must therefore be able to provide the needed strength and quality, to resist these external forces. Strength is measured by aggregate crushing test and aggregate impact test. Abrasion is measured by Los Angels Abrasion Machine

(IS: 2386 -1968).The Indian Roads Congress specifies that the maximum size of aggregates should not exceed ¼th of the concrete thickness. The strength requirements of coarse aggregates are as given the Table 2.5.

Table 2.5. Strength Requirements of Coarse Aggregates for Concrete

Property	For Wearing Surface	Other than Wearing Surfaces
Aggregate crushing value	Not more than 30 %	Not more than 45 %
Aggregate impact value	Not more than 30 %	Not more than 45 %
Abrasion value	Not more than 30 %	Not more than 50 %

b) Water: Water is an essential ingredient used in mixing of concrete. The pH of water should be between 6-8.Water suitable for mixing is also suitable for curing.

GEOMETRIC DESIGN

3. GEOMETRIC DESIGN

3.1. INTRODUCTION

Geometric design standard of the rural roads are important parameters for constructing safe, comfortable and durable roads. These Geometric standards need not be restricted to the minimum values set out and milder standards than the minimum should be preferred where conditions are favorable and the cost is not excessive. Higher standard right in the initial stages may be warranted in cases where improvement of the road geometric at a later date is anticipated due to increased traffic.

The following codes have been published by IRC for providing guidelines on the Geometric Design Standards for Roads.

1) **IRC: 73** Geometric Design Standards for Rural Highways
2) **IRC: 52** Recommendations About the Alignment Survey and Geometric Design of Hill Road
3) **IRC : SP : 23** Vertical Curves for Highways
4) **IRC : 38** Guidelines for Design of Horizontal Curves for Highways and Design Tables
5) **IRC :SP : 48** Hill Road Manual

3.2. TERRAIN CLASSIFICATION

The general slope of the country classifies the terrain across the area. The terrain is an important parameter governing the geometric standards and the criteria given in Table 3.1 should be followed. While classifying a terrain, isolated stretches of varying terrain should not be taken into consideration.

Table 3.1: Terrain Classification (IRC SP : 20 - 2002, Page No. 28)

Terrain Classification	Cross Slope of the Country	
Plain	0-10 %	More than 1 in 10
Rolling	10-25 %	1in 10 to 1 in 4
Mountainous	25-60%	1in 4 to 1 in 1.67
Steep	Greater than 60 %	Less than 1in 1.67

3.3. DESIGN SPEED

Design Speed is a basic criterion for determining all geometric features like horizontal and vertical alignments, super elevation, extra widening of the pavement, length of the horizontal transition curve. The Design speed of roads depend upon

1) Class of road

2) Terrain

The design speed for the rural roads should be taken as given in Table 3.2.

Table 3.2: Design Speeds (IRC SP : 20 - 2002, Page No. 29)

Design Speed (Km/hr)							
Plain Terrain		Rolling Terrain		Mountainous Terrain		Steep Terrain	
Ruling	Min	Ruling	Min	Ruling	Min	Ruling	Min
50	40	40	35	25	20	25	20

Normally ruling design speed should be the guiding criterion for the purpose of geometric design. Minimum design speed may, however, be adopted where site condition and cost does not permit a design based on Ruling Design Speed

3.4. BASIC PRINCIPLE OF GEOMETRIC DESIGN

These Guidelines are intended for uniform practice to achieve optimum design standard for rural roads. As a general rule, geometric features of a road do not allow for stage construction. Improvement of features, like grade, curvature and widening of cross drainage works at a later date can be very expensive and sometimes impossible in remote and hilly area. It is, therefore, necessary that ultimate geometric requirement of rural road should be kept in mind right in the beginning. If stage construction is unavoidable, the permanent works, like, retaining walls, breast wall, and drain, which may have to be altogether rebuilt, may be constructed using dry masonry. Interceptor drain may be located well at the beginning and culverts provided to full width to avoid the need for their widening subsequently. The design standards recommended are absolute minimum. However, the minimum values should be applied only where serious restrictions are implied from technical or economical considerations. General effort

should be to exceed the minimum values as far as possible. Road should be designed so as to have minimum turns and total number of curves in one kilometer should generally be less than 6.

3.5. CROSS-SECTIONAL ELEMENTS

3.5.1. Width of Roadway or Formation

Width of formation or roadway is the sum of the widths of pavements or carriageway including separators (if any) and the shoulders. Formation width is the top width of the highway embankment or the bottom width of the highway cutting excluding the side drains.

Table 3.3: Recommended Roadway Width (IRC SP : 20 - 2002, Page No. 29)

Terrain Classification	Road Width (m)
Plain and Rolling	7.5
Mountainous and Steep	6.0

3.5.2. Right of Way (Road Land Width)

Right of way is the area of land acquired for the road, along its alignment. The width of this acquired land is knows as land width and it depends on the importance of the road and possible future development.

Table 3.4 : Recommended Road Land Width
(IRC SP : 20 - 2002, Page No. 29)

<table>
<tr><th rowspan="3">ROAD CLASSI FICATION</th><th colspan="4">Plain and Rolling Terrain</th><th colspan="4">Mountainous and Steep Terrain</th></tr>
<tr><th colspan="2">Open Area</th><th colspan="2">Built-upArea</th><th colspan="2">Open Area</th><th colspan="2">Built-up Area</th></tr>
<tr><th>Normal</th><th>Range</th><th>Normal</th><th>Range</th><th>Normal</th><th>Excep- tional</th><th>Normal</th><th>Excep tional</th></tr>
<tr><td>Rural Roads (ODR and VR), (m)</td><td>15</td><td>15-25</td><td>15</td><td>15-20</td><td>12</td><td>12</td><td>12</td><td>9</td></tr>
</table>

Note:

1) Additional land width as per requirement may be acquired at locations involving deep cuts, high banks and unstable or landslide prone areas.

2) The lower values of land width may be adopted where the traffic intensity is less than 100 vehicles per day, and where the traffic is not likely to increase due to situation, like dead end, low habitation and difficult terrain condition.

3.5.3. Building and control lines

In order to prevent overcrowding and preserve sufficient space for future road development, it is advisable to lay down restriction on building activity along the rural roads. Recommended standards for building lines and control lines are given in below.

Table 3.5: Recommended Standards for Building and Control Lines (IRC SP : 20 - 2002, Page No. 30)

ROAD CLASSI FICATION	Plain and Rolling Terrain		Mountainous and Steep Terrain	
	Open Area	Built-up Area	Open Area	Built-up Area
	Overall Width Between Bldg. lines	Overall Width Between Control Lines	Distance Between Building Line and Road Boundary (Set-Back)	Distance Between Building Line and Road Boundary (set-back)
Rural Roads (ODR and VR), (m)	25/30*	35	3-5	3-5

**If the land width is equal to the width between the building lines indicated as above, the building line should be set-back by 2.5m from the road land boundary.*

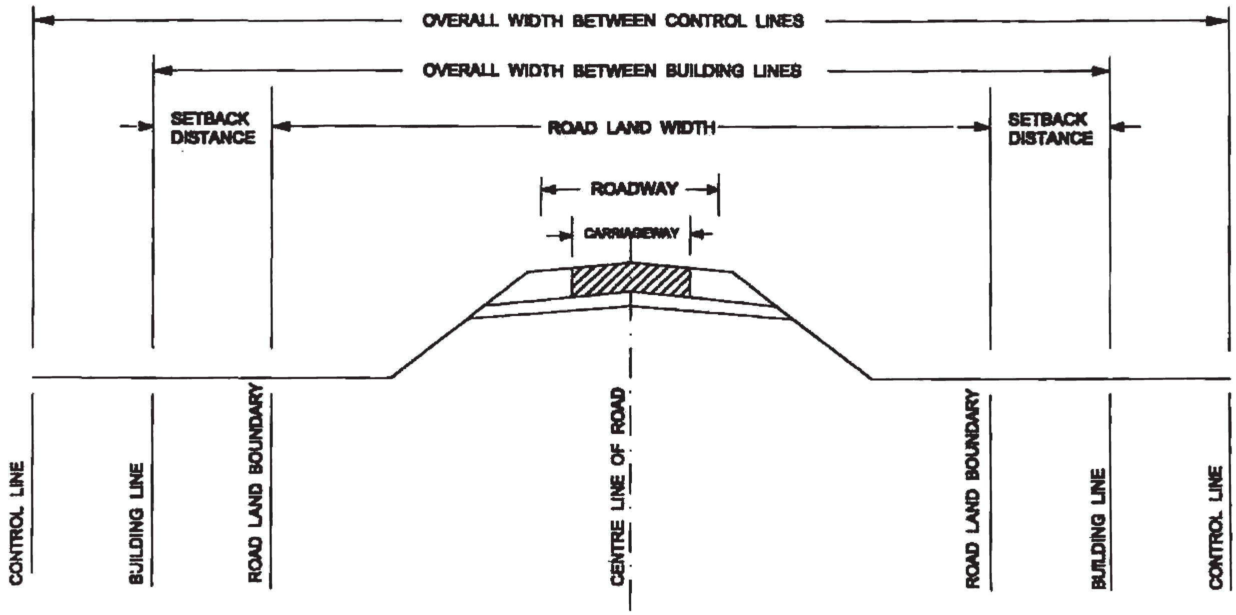


Fig. 3.1. Road Land Boundary, Building Lines and Control Lines

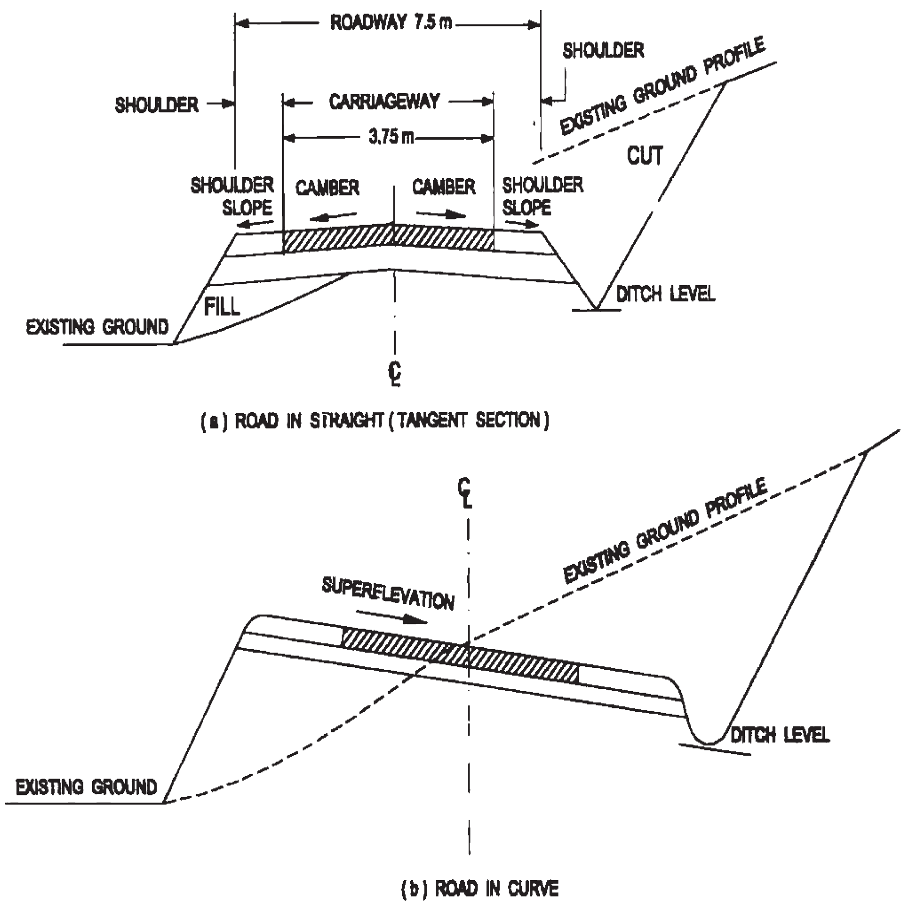


Fig. 3.2. Typical Cross-section in Plain and Rolling Terrain

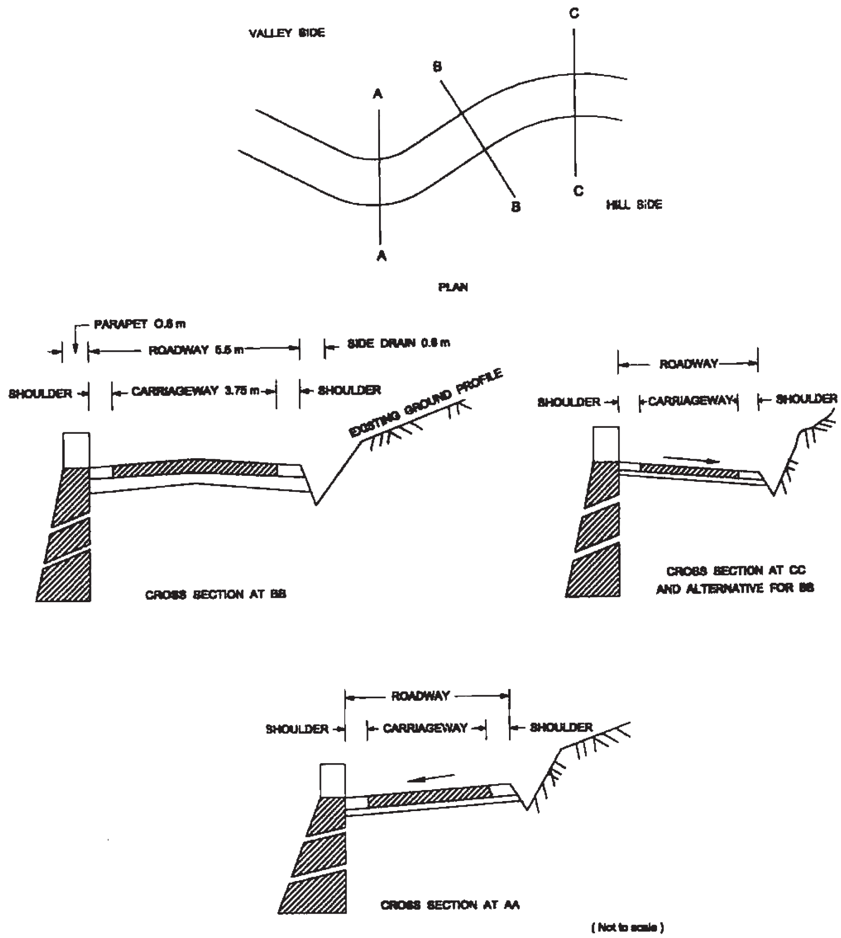


Fig.3.3 Typical-cross in Mountainous and Steep Terrain

3.5.4. Carriageway width

The standard width of the carriage for both plain and rolling as well as mountainous and steep terrain shall be 3.75 m. For rural roads, the carriageway width may be restricted to 3.0 m, where the traffic intensity is less than 100 motorized vehicles per day and where the traffic is not likely to increase due to situation, like, dead end, low habitation and difficult terrain conditions.

3.5.5. Shoulder width

The width of the shoulder for rural roads in different terrain will be one half the differences between the roadway width and carriageway width.

3.5.6. Side slopes

Side slope for rural road where embankment height less than 3.0 m is given in below.

Table 3.6: Side Slope For Rural Roads (IRC SP : 20 - 2002, Page No. 34)

Condition	**Slope (H:V)**
Embankment in Silty/gravelly soil	2:1
Embankment in clay or clayey silt or inundated condition	2.5:1 to 3:1
Cutting in silty/sandy/gravelly soil	1:1 to 1/2:1
Cutting in disintegrated rock or conglomerate	1/2:1 to ¼:1
Cutting in soft rock like shale	¼:1 to 1/8:1
Cutting in medium rock like sandstone, phyllite	1/12:1 to 1/16:1
Cutting in hard rock like quartzite, granite	Near Vertical

3.5.7. Roadway Width at Cross-Drainage Structures

It is difficult to widen cross-drainage structure at a later stage. Therefore, the roadway width should be decided very carefully at the planning stage itself. Causeway and submersible bridge are usually provided on rural roads. High-level bridge on rural road shall be provided only in exceptional cases on merit.

3.5.8. Culvert The roadway width at culvert (measured from outside to outside of the parapet walls) shall be as given below.

Table 3.7: Roadway Width at Culvert (IRC SP : 20 - 2002, Page No. 34)

Terrain	
Plain and Rolling	Mountainous or Steep
7.5 m	6.0 m

3.5.9. Bridge

The roadway width between the kerb for minor and major bridges shall be 5.5m exclusive of parapet. For rural roads, where the traffic is less than 100 motorised vehicles per day and it is not likely to grow due to situations, like, dead end, low

habitation and difficult terrain conditions, the roadway width at bridge may be reduced to 4.25 m.

3.5.10. Causeway and submersible bridge Roadway width at causeway and submersible bridge shall be the same as for culverts.

3.5.11. Camber

The camber on straight section of road should be as recommended as given in below.

Table 3.8: Camber for Different Surface Types
(IRC SP : 20 - 2002, Page No. 35)

Surface Type	Camber (%)	
	Low Rainfall (Annual Rainfall< 1000 mm)	High Rainfall (Annual Rainfall >1000 mm)
Earth road	4	5
WBM and Gravel road	3.5	4
Thin Bituminous Pavement	3	3.5
Rigid Pavement	2	2.5

At super-elevated road sections, the shoulder should normally have the slope of same magnitude and direction as the pavement slope subject to the minimum cross-fall allowable for shoulder. The camber for earth shoulder should be at least 0.5 per cent more than that for the pavement subject to the minimum of 4 per cent. However, 1 per cent more slope than the camber for pavement is desirable.

3.6. SIGHT DISTANCE

The safe and efficient operation of vehicle on roads depends, among other factors on the road length at which an obstruction, if any, becomes visible to the driver in the direction of travel. *Sight distance* available from a point is the actual distance along the road surface, which a driver from a specified height above the carriageway has visibility of stationary or moving objects. The standard for sight distance should satisfy the following three conditions:

1) Driver traveling at the design speed has sufficient sight distance or length of road visible ahead to stop the vehicle, in case of any obstruction on the road ahead, without collision.

2) Driver traveling at the design speed should be able to safely overtake, at reasonable interval, the slower vehicle without causing obstruction or hazard to traffic of opposite direction

3) Driver entering an uncontrolled intersection (particularly unsignalised intersection) has sufficient visibility to enable him to control his vehicle and to avoid collision with another vehicle

Apart from the three situations mention above, the following sight distances are considered by the IRC in Highway design:

3.7. Intermediate sight distance:

This is defined as twice the stopping sight distance. When overtaking sight distance cannot be provided, intermediate sight distance is provided to give the limited overtaking opportunities to fast vehicles.

3.8. Head Light Sight Distance:

This is the distance visible to a driver during night driving under the illumination of the vehicle headlights. This sight distance is critical at up-gradients and at ascending stretch of the valley curves.

3.9. Overtaking Sight Distance :

Overtaking sight distance is the minimum sight distance that should be available to a driver on a two-way road to enable him to overtake another vehicle. The provision of overtaking sight distance is by and large not feasible on hill orads and also not considered for single lane roads.

3.10. STOPPING SIGHT DISTANCE

The minimum sight distance available on a highway at any spot should be of sufficient length to stop vehicle traveling at design speed, safely without collision with any other obstruction. The absolute minimum sight distance is therefore equal to the stopping sight distance, which is also sometimes called non-passing sight distance The sight distance available on a road to a driver at any instance depends on: Features of road ahead

Table : 3.9 Design Values of Stopping, Intermediate and Overtaking sight Distance. (IRC SP : 20-2002, Page No. 35)

Speed (km/h)	Design values (m)		
	Stopping sight Distance	Intermediate sight Distance	Overtaking sight Distance
20	20	40	-
25	25	50	-
30	30	60	-
35	40	80	-
40	45	90	165
50	60	120	235

Table : 3.10 Criteria for Measuring Sight Distance (IRC SP : 20-2002, Page No. 36)

Sight Distance	Driver's Eye Height (m)	Height of object (m)
Safe stopping sight Distance	1.2	0.15.
Intermidiate sight Distance	1.2	1.2
Overtaking sight Distance	1.2	1.2

1) Height of the road ahead
2) Height of the drivers eye above the road surface
3) Height of the object above the road surface

The features of the road ahead, which affect the sight distance, are the horizontal alignment and vertical profile of the road, the traffic conditions and the position of obstructions. For the purpose of measuring the stopping sight distance or visibility ahead, IRC has recommended height of eye level of driver as 1.2m and the height of the object as 0.15m above the road surface.

The distance within which a motor vehicle can be stopped depends upon the factors listed below:

1. Total reaction time of the driver
2. Speed of the vehicle
3. Efficiency of the brakes
4. Frictional resistance between the road and the tyres
5. Gradient of the road

3.11. HORIZONTAL CURVES

A horizontal highway curve is a curve in plan to provide change in direction to the central line of road. When a vehicle traverses a horizontal curve, the centrifugal force acts horizontally outwards through the centre of gravity of the vehicle.

The centrifugal force development depends on the radius of the horizontal curve and the speed of the vehicle negotiating the curve. This centrifugal force is counteracted by the transverse frictional resistance developed between the tyres and the pavement which enables the vehicle to change the direction along the curve and to maintain the stability of the vehicle.

The centrifugal force acting on a vehicle negotiating a horizontal curve has two effects: (i) Tendency to over turn the vehicle about the outer wheel and (ii)Tendency to skid the vehicle laterally.

The analysis of stability of those two conditions against overturning and transverse skidding of the vehicle negotiating horizontal curves without super elevation are given below:

3.11.1. Over turning effect

The centrifugal force that tends the vehicle to over turn about the outer wheel B on a horizontal curve. The over turning moment due to centrifugal force P is PX h; This is resisted by the restoring moment due to weight of the vehicle W and is equal to W.b/2, where h is height of the centre of gravity of the vehicle above the road surface and b is the width of the wheel track of the vehicle. The stability condition for overturning will occur when Ph=Wb/2h. This means that there is danger of over turning when the centrifugal ratio P/W or $v^2/g*R$ attains a value of b/2h

3.11.2. Transverse skidding effect

The centrifugal force developed also has the tendency to push the vehicle outwards in the transverse direction. If the centrifugal force P developed exceeds the maximum possible transverse skid resistance due to the friction, the vehicle will start skidding in the transverse direction. The equilibrium condition for the transverse skid resistance developed is given by: P=Fa+Fb= f (Ra+Rb) =Fw

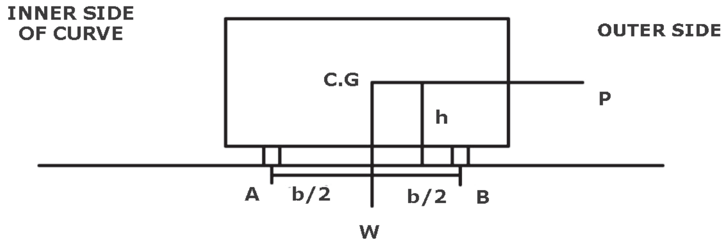


Fig.3.4. Overturning due to Centrifugal Force

F is the coefficient of friction between the tyre and the pavement surface in the transverse direction Ra and Rb are normal reaction at the wheel A and B such that (Ra+Rb) is equal to the weight w of the vehicle, as no super elevation has been provided in this case.

Since P=f x W, the centrifugal ratio P/W is equal to 'f'.

In other words when the centrifugal ratio attains a value equal to the coefficient of lateral friction there is danger of lateral skidding.

Thus to avoid overturning and lateral skidding on a horizontal curve, the centrifugal ratio should always be less than b/2h. If the pavement is kept horizontal across the alignment, the pressure on the outer wheels will be higher due to the centrifugal force acting outwards and hence the reaction Rb at the outer wheel would be higher. The difference in pressure distribution at inner and outer wheels has been indicated in figure.10 When the limiting equilibrium condition for over turning occurs, the pressure at the inner wheels becomes equal to zero.

3.11.3. SUPER ELEVATION

In order to counter act the effect of centrifugal force and to reduce the tendency of the vehicle to over turn or skid, the outer edge of the pavement is raised with respect to inner edge, thus providing a transverse slope throughout the length of the horizontal curve. This transverse inclination to the pavement surface is known as super elevation or cant or banking. The super elevation "e" is expressed as the ratio of the height of outer edge with respect to the horizontal width.

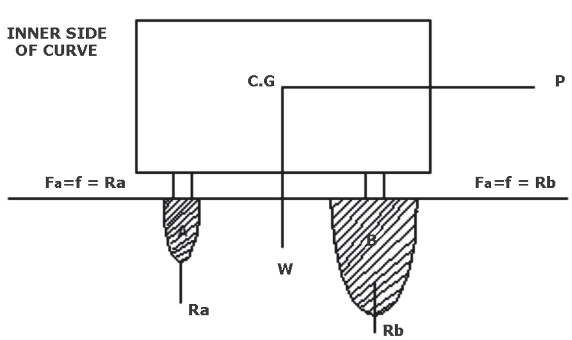


Fig.3.5.Shaded Area shows the Pressure under the inner and outer Wheels A and B

Super elevation is provided to counteract centrifugal force on moving vehicles at horizontal curves and it is calculated from the following formula :

$$e = v^2 / 225 R$$

where e = super elevation (%)

v = speed in km/hr

R = radius of curve in meters

Super elevation obtained from the above expression should, however be kept limited for the following values:

Plain and rolling terrain	-	7 percent
Snow bound area	-	7 percent and
Hilly area but not snow bound	-	10 percent

3.11.3.1. Analysis of Super Elevation

The forces acting on the vehicle while moving on a circular curve of radius R meters, at speed of v m/sec are

1) The centrifugal force $P = \frac{W \times v^2}{gR}$ acting horizontally outwards through the centre of gravity, CG.

2) The weight W of the vehicle acting vertically downwards through the CG.

3) The frictional force developed between the wheels and the pavement acting transversely along the pavement surface towards the centre of the curve.

The centrifugal force is thus opposed by corresponding value of the friction developed and by a component of the force of gravity due to the super elevation provided. Figure.3.6 shows the cross section of a pavement with all the forces acting on the vehicle resolved parallel and perpendicular to the inclined road surface. Considering the equilibrium of the component of forces acting parallel to the plane, ($P\cos\theta$) the component of centrifugal force is opposed by ($W\sin\theta$) the component of gravity and frictional forces F_a and F_b.

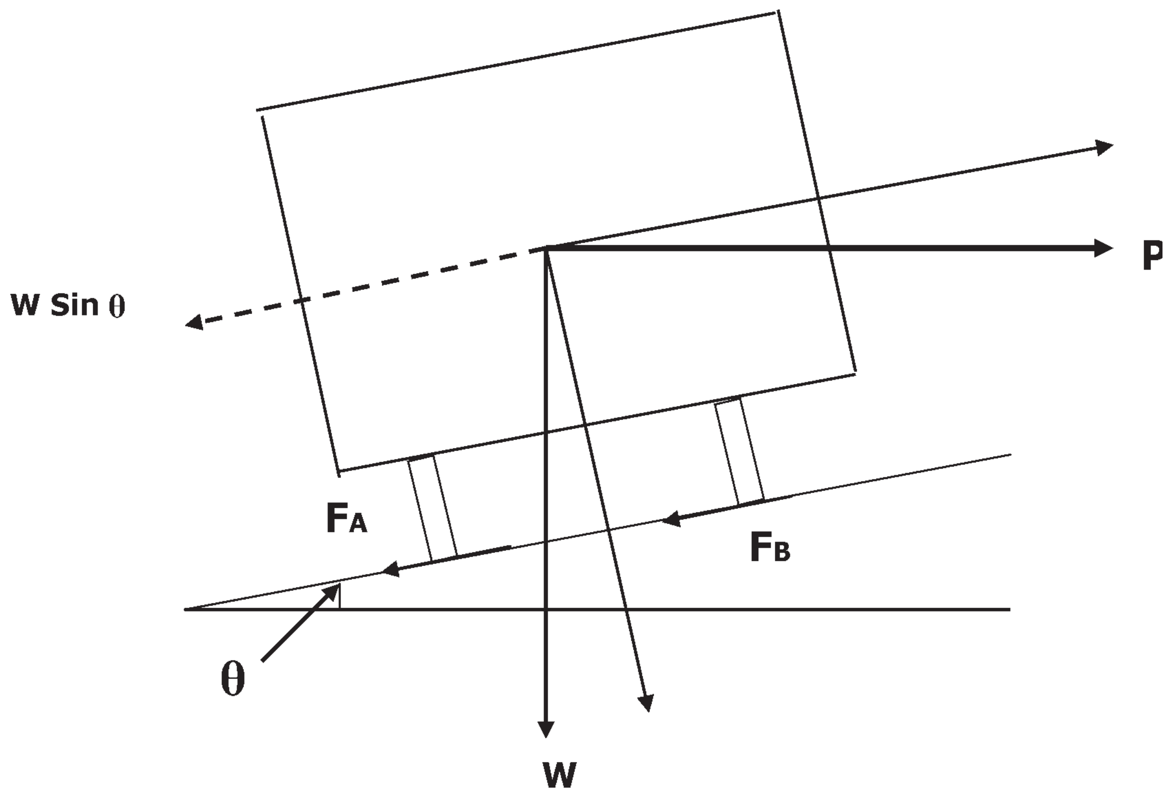


Fig. 3.6. Analysis of Superelevation

e= tan θ

Governing Equation **$e+f = V^2/gR$**

Table 3.11. Radii Beyound which Superelevation Not Required (IRC SP : 20 - 2002, Page No. 38)

Design Speed (km/h)	Radius (m)			
	4 per cent Camber	3 per cent Camber	2.5 per cent Camber	2.0 per cent Camber
20	50	60	70	90
25	70	90	110	140
30	100	130	160	200
35	140	180	220	270
40	180	240	280	350
50	280	370	450	550

3.11.4. Horizontal Alignment

General guidelines (IRC SP : 20 - 2002, Page No. 36)

1) The alignment should be as directional, fluent and matching well with the surrounding topography as for as possible and also to avoid abrupt changes.

2) On new roads the curves should be designed to have the largest practical radius generally not less than the ruling value corresponding to ruling design speed given in table 2.

3) Absolute minimum values based on minimum design speed may be used where economics of construction and site condition so dictates. The radii below the absolute minimum should not be provided.

4) Straight section exceeding 3Km length should be avoided. A curvilinear alignment with long curve is of safety and aesthetic.

5) Sharp curves should not be introduced at the end of long tangents, since these can be extremely hazardous.

6) Curve should be sufficiently long and have suitable transition curves at either end to eliminate the shock due to application of centrifugal force. For deflection angle less than 1 degree no curve is required to be designed.

7) Reverse curves may be needed in difficult terrain. Sufficient length between two curves shall be provided for introduction of requisite transition curve.

8) To avoid distortion in appearance, the alignment should co-ordinate with longitudinal profile.

Minimum radius of Horizontal Curves

A horizontal curve consists of a circular portion raised on the outer edge and flanked by transitions at either end as shown in Figure 3.7. Various design elements of a horizontal curve include radius (R), superelevation (e), transition curve, widening and sight distance. For the design speeds suggested in section 3, values of R and e are so selected that both fall within the prescribed limits as given in subsequent sections.

(i) Minimum radius of horizontal curve can be determined from the formula :

$$R = \frac{v^2}{127\,(e + f)}$$

where v = speed in km/hr

R = radius in meters

e = super elevation (%)

f = coefficient of side friction (= 0.15 as per IRC).

Table 3.12. Minimum Radii of Horizontal Curves
(IRC SP : 20 - 2002, Page No. 38)

<table>
<tr><th rowspan="3">Road Category</th><th colspan="2" rowspan="2">Plain Terrain</th><th colspan="2" rowspan="2">Rolling Terrain</th><th colspan="4">Mountainous Terrain</th><th colspan="4">Steep Terrain</th></tr>
<tr><th colspan="2">Areas not affected by snow</th><th colspan="2">Areas affected by snow</th><th colspan="2">Areas not affected by snow</th><th colspan="2">Areas affected by snow</th></tr>
<tr><th>Ruling Minimum</th><th>Absolute Minimum</th><th>Ruling Minimum</th><th>Absolute Minimum</th><th>Ruling Minimum</th><th>Absolute Minimum</th><th>Ruling Minimum</th><th>Absolute Minimum</th><th>Ruling Minimum</th><th>Absolute Minimum</th><th>Ruling Minimum</th><th>Absolute Minimum</th></tr>
<tr><td>Rural Roads (ODR and VR)</td><td>90</td><td>60</td><td>60</td><td>45</td><td>20</td><td>14</td><td>23</td><td>15</td><td>20</td><td>14</td><td>23</td><td>15</td></tr>
</table>

Note : Ruling Minimum and absolute minimum radii are for ruling design speed and minimum design speed respectively vide Table. 3.2

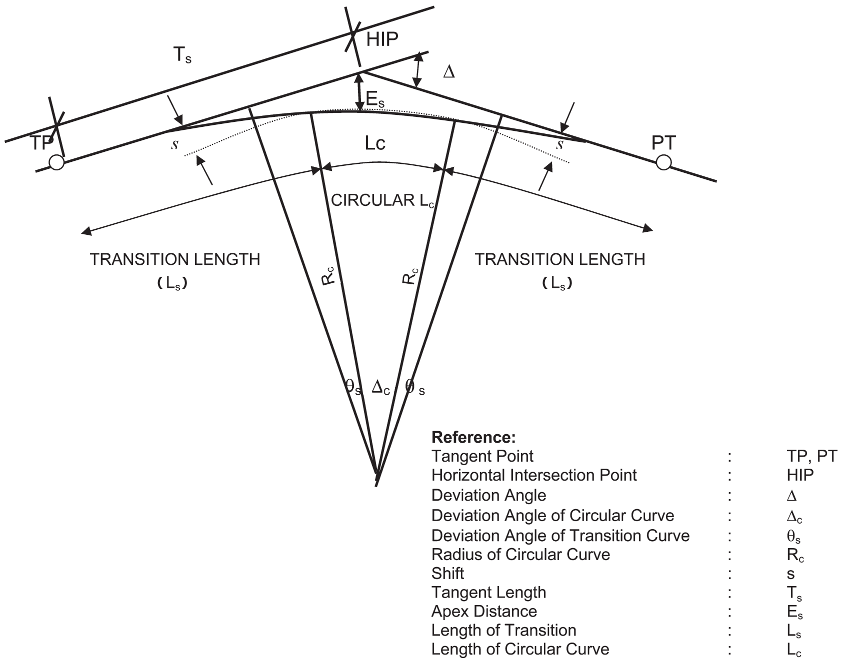


Fig : 3.7 Components of Horizontal Curve

The details of Horizontal Curve may be given in the following format in road estimate.

Sl. No.	Chainage at	Radius of Curve (Rc) in 'm'	Length of Curve (LC) in 'm'	Transition Length (Ls) in 'm'	Super elevation (e) in 'm'	Extra Widening in 'm'

3.11.5. Transition curve :

Spiral curve should be used for transition. This is necessary for a vehicle to have smooth entry from a straight section into a circular curve. The transition curve also improves aesthetic appearance of the road besides permitting gradual application of the superelevation and extra widening of carriageway needed at the horizontal curve. Transition curve is provided at both ends of horizontal curve. Minimim length of transition curves for various radii are given in Table 3.13 & 3.14. For deriving values of the individual elements like shift, tangent distance, apex distance, etc., and working out co-ordinates to lay the curves in the field, it is convenient to use curve tables. For this, reference may be made to IRC:38.

A transition curve has a radius which decrease from infinity at the tangent point to a designed radius of the circular curve .when a transition curve is introduced between a straight and circular curve, the radius of transition curve decrease and becomes minimum at the beginning of the circular curve. The rate of change of radius of the transition curve will depend on the equation of curve and its shape. The Objectives of providing transition curves:

1) To introduce gradually the centrifugal force between the tangent point and the beginning of the circular curve, avoiding a sudden jerk on the vehicle.
2) To enable the driver turn the steering gradually for his own comfort and security.
3) To enable gradual introduction of the designed super elevation and extra widening of pavement at the start of the circular curve.
4) To improve the aesthetic appearance of the road.

Different types of transition curves:

1) Spiral (also called as clothoid)
2) Lemniscate
3) Cubic parabola

The ideal shape of transition curve should be such that the rate of introduction of centrifugal force or the rate of change of centrifugal acceleration should be consistent. The IRC recommends the use of spiral curve as transition curve due to the following reasons;

1) The spiral curve satisfies the requirement of an ideal transition curve.
2) The geometric property of spiral may is such that the calculations and setting out the curve in the field is simple and easy.

3.11.5.1. Calculation of length of transition curve

The length of transition curve is designed to fulfill three conditions:

1. Rate of change of centrifugal acceleration :

$Ls= 0.0215V^3/CR$

Where,

Ls= length of transition curve, m

V= design speed in kph.

C= allowable rate of change of centrifugal acceleration m /sec ^{3},

C=80/(75+V) R = radius of circular curve in m.

3.2. Rate of introduction of super elevation:

Ls= (e x N)/2 x (W+We), when the pavement is rotated about the centre. Ls= (e x N) x (W+We), when the pavement is rotated about the inner edge. Where, 1 in N = the rate of change of super elevation, and is equal to 150 in open country, 100 in built up areas and 60 in hilly roads. e = super elevation W = width of carriage way in m. We = the total extra widening at horizontal curves in m.

3.3. By empirical formula given by IRC:

a) For plain and rolling terrain: $Ls=2.7V^2/R$

b) For mountainous and steep terrain;

$Ls= V^2/R$ The maximum value of above three criterions will be taken as the length of the transition curve.

Table 3.13
Transition Lengths for Different Speeds and Curve Radii in Plain and Rolling Terrain (IRC SP : 20 - 2002, Page No. 39)

Curve Radius (meters)	Transition Length (meters) for Design Speed of		
	50 km/h	40 km/h	35 km/h
45	NA	NA	70
60	NA	75	55
90	75	50	40
100	70	45	35
150	45	30	25
170	40	25	20
200	35	25	20
240	30	20	NR
300	25	NR	NR
360	20	NR	NR
400	20	NR	NR
500	NR	NR	NR
600	NR	NR	NR
700	NR	NR	NR

NA – Not applicable
NR – Not required

Table 3.14
Transition Lengths for Different Speeds and Curve Radii in Mountainous & Steep Terrain (IRC SP : 20 - 2002, Page No. 39)

Curve Radius (meters)	Transition Length (meters) for Design Speed of		
	30 km/h	25 km/h	20 km/h
15	NA	NA	30
20	NA	35	20
25	NA	25	20
30	30	25	15
40	25	20	15
50	20	15	15
55	20	15	15
70	15	15	15
90	15	15	NR
120	15	NR	NR
150	15	NR	NR

NA – Not applicable
NR – Not required

3.11.6. Widening at curves :

At sharp horizontal curve, it is necessary to widen the carriageway to facilitate safe passage of vehicles. The extra width to be provided to horizontal curve are given in Table 3.15. The widening should be effected by increasing the width at an approximately uniform rate along the transition curve. The extra width should be continued over the full length of the circular curve.

The widening should be done on both sides of the carriageway, except that on hill roads it will be preferble if the entire widening is done only on the inner side of the curve. Similarly, the widening should be provided only on the inside when the curve is plain circular and has no transition.

On curves in Plain and Rolling Terrain, having no transition (i.e Curve radius (Rc) $\leq$ 60 m and $\geq$500 m for design speed of 50 km/h), widening should be achieved in the same way as the superelevation i.e. two-third being attained on the straight section before start of the curve and one-third on the curve.

Table 3.15 Widening of Pavement at Curve (IRC SP : 20 - 2002, Page No. 39)

Radius of Curve (m)	Upto 20	21-60	Above 60
Extra Widening for 3.75 m Wide Single Lane Carriageway. (m)	0.9	0.6	Nil

3.11.7. Set back Distance (m) at horizontal curves

The clearance distance required from the centre line of a horizontal curve to an obstruction on the inner side of the curve to provide adequate sight distance is known as set back distance. It depends upon the following factors:

1) Required sight distance, S

2) Radius of horizontal curve, R

3) Length of the curve, Lc which may be greater than S

On single lane roads the setback distance is calculated using the following equation

$m = R-(R-n) \cos \Phi$

Where $\Phi = S/2(R-n)$ radians

m = The minimum set back distance from the centre line of the road in metres

R = Radius of the center line of the road in metres.

N = Distance between the center line of the road and the inside lane in metres

S = Required sight distance in metres

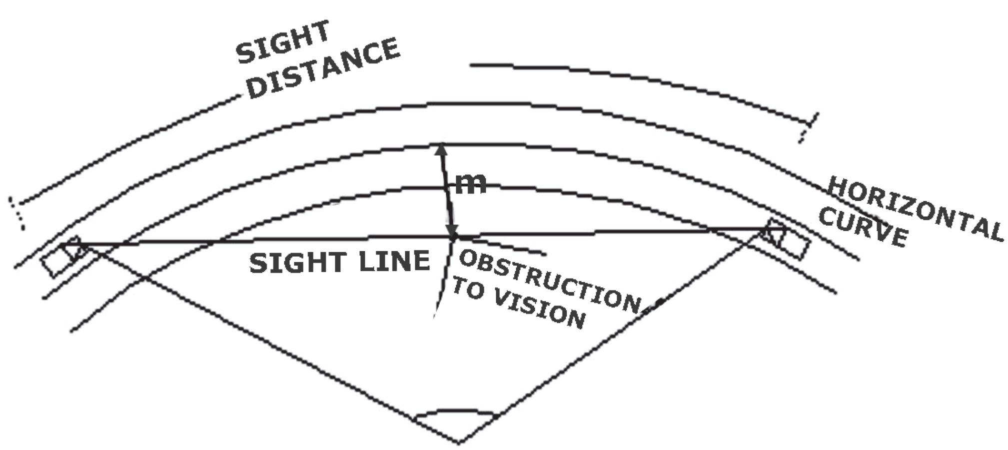


Fig. 3.8 Set-back Distance at Horizontal Curves

Table 3.16: Recommended Setback Distance for single lane carriageway (IRC SP : 20 - 2002, Page No. 40)

Radius of circular curve (m)	Set- back distance (m)				
	S=20m (v=20 kph)	S=25m (v=25kmph)	S=30m (v=30kmph)	S=45m (v=40kmph)	S=60m (v=50kmph)
14	3.4	-	-	-	-
15	3.2	-	-	-	-
20	2.4	3.8	-	-	-
23	2.1	3.3	-	-	-
30	1.7	2.6	3.7	-	-
33	1.5	2.3	3.4	-	
50	1.0	1.6	2.2	5.0	-
60	-	1.3	1.9	4.2	-
80	-	1.0	1.4	3.1	5.6
100	-	0.8	1.1	2.5	4.5
120	-	0.7	0.9	2.1	3.7
150	-	0.5	0.5	1.7	2.3

- Set-back distance for intermediate sight distance and over taking sight distance can be computed similarly. But the clearance required is usually too large to be economically feasible except on very flat curves.
- Where there is a hill slope on the inner side of horizontal curve, the average height of sight line for stopping sight distance is 0.7m for deciding the extent of clearance.
- Cut slope should be kept lower than sightline demarcating the set-back distance, either by cutting back the slope (or) by benching suitably.
- In the case of intermediate and over taking sight distance, height of sight of line above ground line should be taken as 1.2m.
- In situations where horizontal and vertical curves overlap, design should provide for the required sight distances both in the vertical direction along the pavement and in the horizontal direction on the inner side of the curve.

3.12. VERTICAL ALIGNMENT

The designer has to always keep an eye on economy in selecting the alignment and the longitudinal profile. It is general practice to follow as closely as possible the natural terrain profile. Desirably there should be no change within the distance of 150m.Two vertical curves in same direction with a short tangent should be avoided. The longitudinal profile should be coordinated suitably with the horizontal alignment. Decks of small cross drainage structures (culverts and minor bridges) should follow the same profile as the flanking road section without any break in the grade line.

3.12.1. Gradient

The rate of rise or fall with respect to the horizontal along the length of road expressed as ratio or a percentage is termed as the “gradient”. Gradient should be carefully selected keeping in view the design speed and terrain. While aligning a highway, the gradient is decided for designing the vertical curve. The engineer has to consider all aspects such as construction cost, practical problems in construction at the site, and the vehicle operation cost in such alternative proposals before finalizing the gradients. Gradients are divided into the following categories.

- Ruling gradient
- Limiting gradient
- Exceptional gradient
- Minimum gradient

3.12.1.1. Ruling gradient

It is a gradient which in the normal course must never be exceeded in any part of the road. Hence, ruling gradient is also known as design gradient. However, flatter gradients may be preferred wherever practicable. The selection of ruling gradient will depend upon several factors such as type of terrain, the length of the grade, the speed, pulling power of vehicles and presence of horizontal curves.

3.12.1.2. Limiting gradient

It is a gradient steeper than the ruling gradient, which may be used, in restricted lengths where keeping within the ruling gradient is not possible. However, the length of continuous grade line steeper than ruling value should be limited.

3.12.1.3. Exceptional gradient

It is a gradient steeper than the limiting gradient which may be used in short stretches only in extra-ordinary situations.

3.12.1.4. Minimum gradient

The road can be level, with little or no gradient in such cases there will be problems of drainage. Though the surface water can be drained off to the side drains by Providing proper camber on the pavement surface and cross slope on shoulders , a certain longitudinal slope is essential ,to drain the water along the drains, depending on the surface of the drains. Hence, it is desirable to have a certain minimum gradient. The minimum gradient would depend on rainfall runoff, type of soil, topography and other site conditions.

Table 3.17: Minimum Gradient

Minimum gradient	Type of drains
1 in 500	Concrete drains or gutter
1 in 200	Inferior surface drains
1 in 100	Kutcha open drains

Gradient up to the ‘ruling gradient’ may be used as a normal course in design where ‘limiting gradients’ may be used where the topography of a place compels this or where the adoption of gentler gradients would involve additional costs. In such case also, the length of continuous grades steeper than the ruling gradients should be as short as possible.

Exceptional gradients are meant to be adopted only in very difficult situations and for short length not exceeding 100m at a stretch. In mountainous and steep terrain, successive stretches of exceptional gradients must be separated by a minimum length of 100m having gentler gradients. The rise in elevation over a 2 km length shall not exceed 100m in mountainous and 120m in steep terrains. In a hilly terrain, gradient should be such that it can be negotiated with the least change of gears by heavier vehicles to save time and operation cost.

Table 3.18 : RECOMMENDED GRADIENTS FOR DIFFERENT TERRAIN CONDITIONS (IRC SP : 20 - 2002, Page No. 41)

Terrain	Ruling gradient	Limiting gradient	Exceptional gradient
Plain & Rolling	3.3 percent (1 in30)	5 percent (1 in 20)	6 percent (1 in16.7)
Mountainous terrain and steep terrain having elevation more than 3,000m above the mean sea level	5 percent (1 in 20)	6 percent (1in 16.7)	7 percent (1 in 14.3)
Steep terrain having elevation less than 3,000m Above the mean sea level	6 percent (1 in16.7)	7 percent (1 in 14.3)	8 percent (1 in 12.5)

In the plain area ,as well as the road is used by slow moving bullock carts and motor vehicles, gradient adopted should be such that it will not have adverse effect on bullock cart traffic.

3.13. Grade Compensation at Curves

At horizontal curves, due to the turning angle of the vehicles, the curve resistance will develop. When there is a horizontal curve in addition to the gradient, there will be increased resistance to friction due to both gradient and curve. It is necessary that in such cases the resistance due to curve and gradient should not exceed the resistance due to the maximum value of the grade specified. Therefore, at horizontal curves, the gradients should be eased by an amount known as the" Grade Compensation" which is intended to offset the requirements of extra tractive effort at curves.

This may be calculated from the following formula:

Grade compensation (percent) = (30+R)/R

Subject to maximum of 75/R, where R is the radius of the curve in meters. Since Grade compensation is not necessary for gradients flatter than 4 percent, When applying grade compensation correction, the gradients need not be eased beyond 4 per cent.

3.14. Vertical Curves

Vertical curves are introduced for smooth transition at grade changes. The vertical curves may be classified into two categories. 1. Summit curves or crest curves with convexity upwards. 2. Valley or sag curves with concavity upwards.

Both summit curves and valley curves should be designed as parabola, the length of the vertical curves is controlled by sight distance requirements, but curves with greater lengths are aesthetically better. Curves should be provided at all grade changes exceeding those given in below.

Table 3.19: Minimum length of Vertical curve (IRC SP : 20 - 2002, Page No. 42)

Design speed (kph)	Maximum grade change (%) not requiring a vertical curve	Minimum length of vertical curve in (m)
Upto 35	1.5	15
40	1.2	20
50	1.0	30

Notes on aligment co-ordination

1. Vertical and horizontal curves should coincide. If not possible, the horizontal curve should be somewhat longer than the vertical curve.
2. Sharp horizontal curves should be avoided at or near apex of pronounced summit/valley curves.
3. Grade and curvature should be in proper balance. Flat horizontal curves at the expense of steep or long grades, or sharp curvature with flat grades should be avoided.
4. Broken-back curves (two curves in the same direction with shour tangent in-between) both in alignment and profile should be replaced by a single curve.

3.14.1. Summit curve The length of summit curve is governed by the choice of sight distance according to the operating condition of road. The required length may be calculated from the formulae given in Table 3.20.

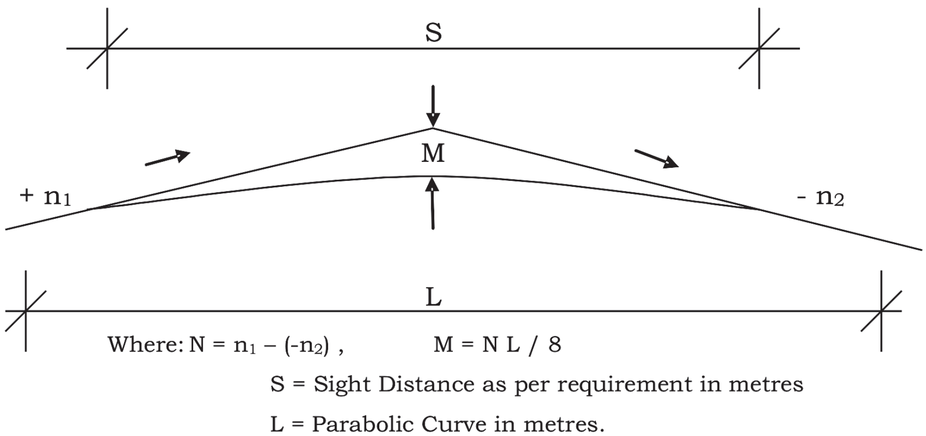


Fig : 3.9. SUMMIT CURVE

Table 3.20: Length of summit curve (IRC SP : 23 - 1993)

Case	For stopping sight distance	For intermediate sight distance / overtaking sight distance
L > S	$L=NS^2/4.4$	$L= NS^2/9.6$
L< S	L= 2S-(4.4)/N	L= 2S-(9.6)/N

Where

N = deviation angle, i.e. the algebraic difference between the two grades.

L = Length of parabolic vertical curve in metres.

S = Sight Distance in metres.

Note : 1. For summit curves, overtaking sight distance should be the general criterion.Where not feasible, intermediate sight distance should be adopted as the next best. Safe stopping sight distance is the absolute minimum.

2. For valley curves, safe stopping sight distance should be adopted.

3.14.2. Valley Curve

The length of valley transition curve is designed based on the two criteria

1) The allowable rate of change of centrifugal acceleration of 0.6 m/sec^3 and

2) The head light sight distance, and the higher of the two values may be adopted.

Usually the second criterion of head light sight distance is higher and therefore governs the design.

1. The length of valley transition curve according to first criteria i.e. for comfort condition is given by

$$\mathbf{L = 0.38\ (NV^3)^{1/2}}$$

2. The length of valley curve according to the second criteria may be calculated by using the formulae given in below.

Table 3.21: Length of Valley Curve (IRC SP : 23 - 1993, Page No. 21)

Case	Length of valley curve
$L > S$	$L = NS^2/(1.5+0.035\ S)$
$L < S$	$L = 2S-(1.5+0.035\ S)/N$

Where

N = deviation angle, i.e. the algebraic difference between the two grades

L = Length of parabolic vertical curve in metres

S = sight distance requirements in metres.

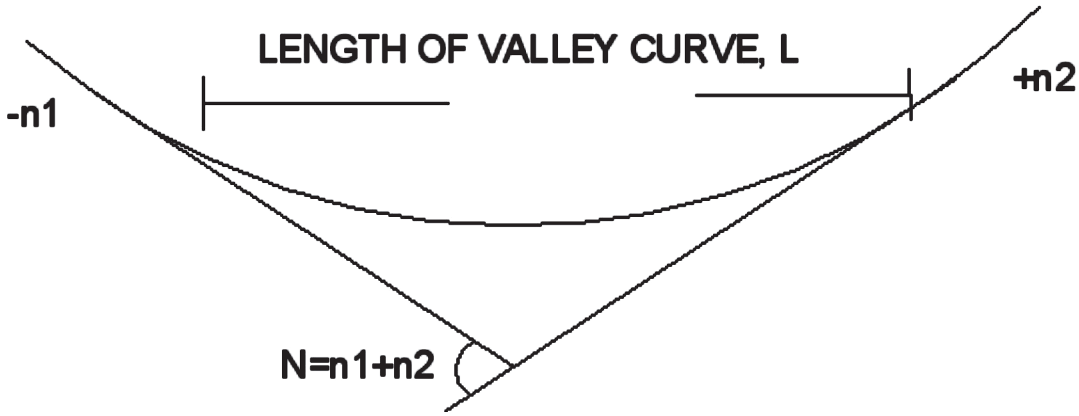


Fig.3.10. Length of Valley Curve

3.15. ALIGNMENT COMPATIBILITY

As a general rule, changes in horizontal and vertical alignment should be phased to coincide with each other, i.e., the vertical curve should roughly extend from the commencement of to the end of the corresponding horizontal curve. Preferably, the horizontal curve should be somewhat longer than the vertical curve. Sharp horizontal curve should not be introduced at or near the top of the summit curve or the lowest point of valley curve.

3.16. HAIR-PIN BENDS

A hairpin bend may be designed as a circular curve with transition at each end. Alternatively, compound circular curves may be provided.

Minimum deisgn speed		20 Km/h
Minimum roadway at Apex		7.50 m
Minimum radius for the inner curve		14.00 m
Minimum length of transition curve		15.00 m
Gradient	Maximum	1 in 40 (2.5 percent)
	Minimum	1 in 200 (0.5 percent)
Super elevation		1 in 10 (10.0 percent)

The inner and outer edge of the road way should be concentric with respect to centre line of the pavement. Where a number of hair-pin bends have to be introduced, a minimum intervening distance of 60 m should be provided between the successive bends to enable the driver to negotiate the alignment smoothly.

At Hair-pin bends, generally widening can be achieved only by cutting the hill side, and preferably the full roadway width should be surfaced.

3.17. PASSING PLACES

On hill roads passing places are required to facilitate crossing of vehicles. These should be provided at the rate of 2 to 3 per kilometer. The exact location should be judiciously decided on the basis of site conditions. The length of passing place should be about 20 to 30m long with a carriageway width of 5.5m.

3.18. LATERAL AND VERTICAL CLEARANCE

Lateral clearance:

It is desirable that the full roadway width at the approaches should be carried through the underpass. This implies that the minimum lateral clearance (i.e., the distance between the extreme edge of the carriageway and the face of the nearest support whether a solid abutment, pier or column) should be equal to the normal shoulder width.

Vertical clearance:

The minimum vertical clearance of 4.5m should be ensured over the full width of the roadway at all underpasses, and similarly at overhanging cliffs. The vertical clearance should be measured in reference to the highest point of the carriageway, i.e., the crown or the super elevated edge of the carriageway as the case may be. Due allowance for any future raising/strengthening of the pavement should also be made.

3.19. TRAFFIC ENGINEERING REQUIREMENTS

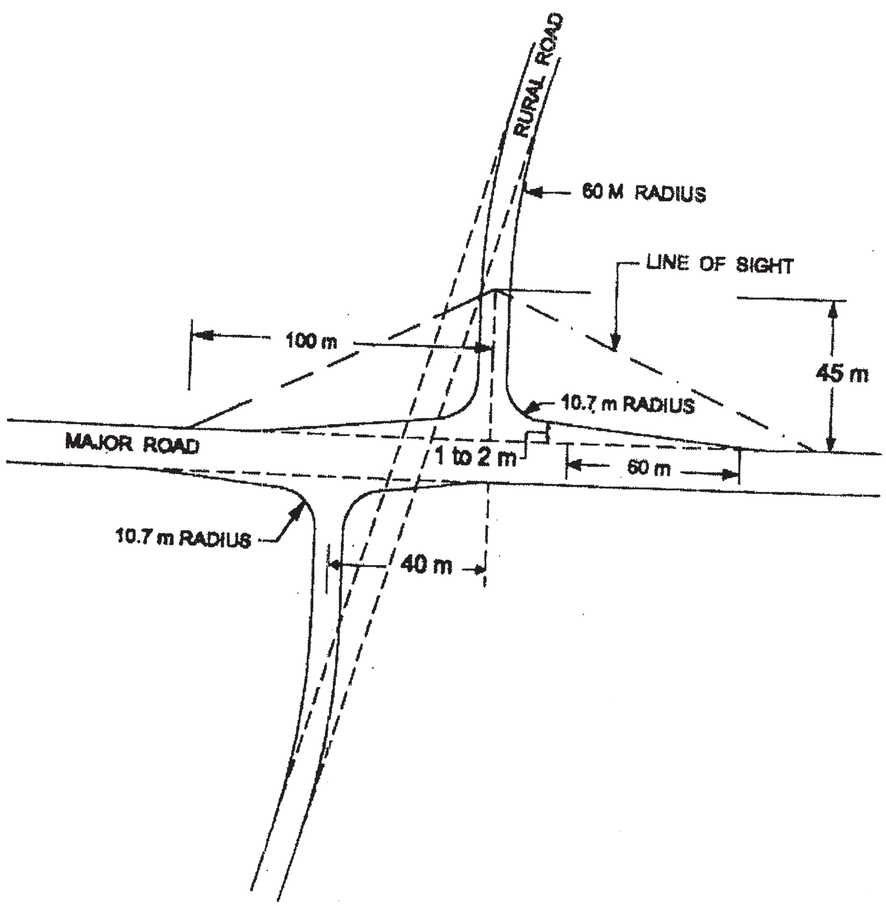
The rural roads are low volume (traffic) low speed roads with maximum design speed of 50 kmph. The geometric designs detailed in this chapter adequately fulfills the requirements of the traffic that is likely to use roads. However, a few features need careful considerations to maintain safety and convenience of the vehicles using these roads.

3.19.1 INTERSECTION WITH OTHER ROAD

A rural road quite often meets or crosses another road of the higher category. In such situations the junction layout is required to be provided in such a way that the safety of the vehicles leaving the higher category of road and joining the rural road or those which join the higher category of road from the rural road is maintained adequately. As the higher category of the road will normally have wider right-of-way provision, the intersection is to be flared along the higher category of road. The figure also shows that the rural road should not meet the other road at an angle other than 90º. Thus, wherever such conditions prevail, effort should be made to realign the road near the junction.

3.19.2 OTHER TRAFFIC ENGINEERING FEATURES

The rural roads are designed and constructed as single lane road with sealed or unsealed surface depending on traffic and other criteria. Thus, there is no requirement of pavement marking. Regarding the signs, the following requirements should be met.



3.19.2.1 Stop Sign

When rural roads meet each other, the junction should be a stop sign controlled junction, and minor road meeting any higher category of roads, the traffic joining the higher type road shall be controlled by a stop sign.

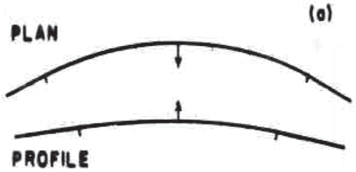
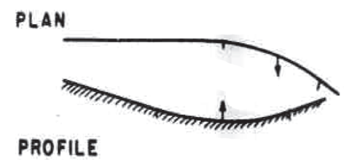
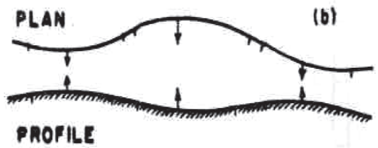
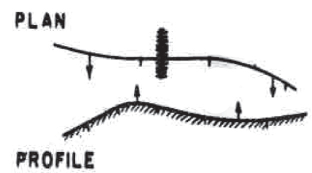
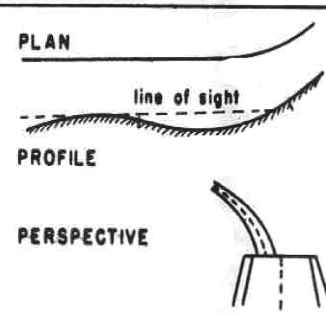
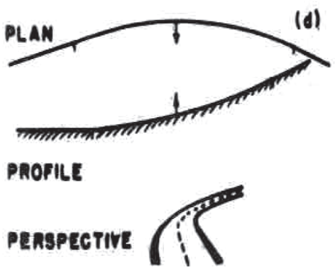
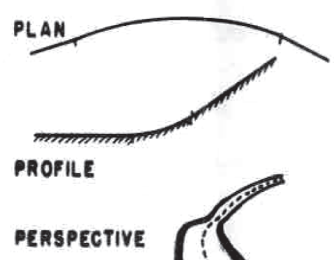
3.19.2.2 Direction Sign

The rural road shall have all the necessary direction signs as per the requirement of road signage recommends by IRC.

3.19.2.3 Kilometer Stone

The rural road shall have kilometer stone of standard size as given by IRC with top rounded portion paints in orange colour.

STRETCHES INDICATING GOOD AND BAD ALIGNMENT COORDINATION (IRC 73 -1980, Plate No.7)

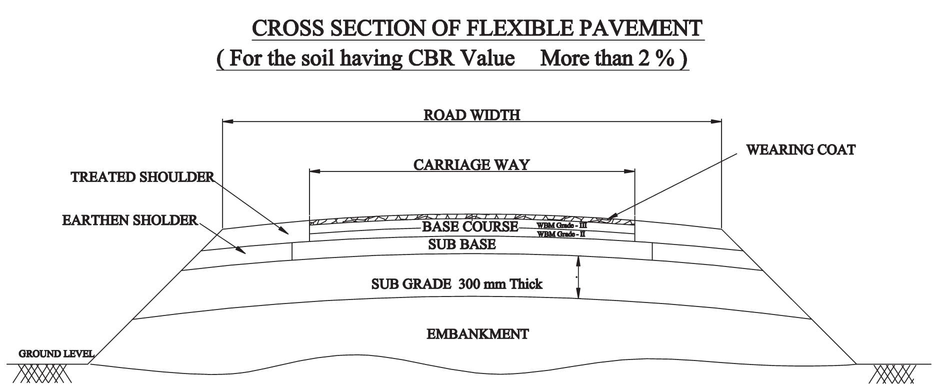
GOOD DESIGN FORM		UNDESIRABLE DESIGN FORM	
(a) 	VERTICES OF HORIZONTAL AND VERTICAL CURVES COINCIDE. VERTICAL CURVE KEPT WITHIN HORIZONTAL CURVE. BRINGS OUT A VERY PLEASING APPEARANCE.		VERTICAL CURVE PRECEDES HORIZONTAL CURVE. HORIZONTAL CURVE LOOKS LIKE A SHARP KINK. POOR APPEARANCE.
(b) 	SAME AS (a) BUT INVOLVING A SERIES OF CURVES VERTICES OF HORIZONTAL AND VERTICAL CURVES COINCIDE, PRODUCING A VERY PLEASING APPEARANCE.		HAZARDOUS LEVEL CROSSING (OR ROAD INTERSECTION) AND SHARP HORIZONTAL CURVE ARE OBSCURED FROM DRIVER'S VIEW BY SUMMIT CURVE. DANGEROUS SITUATION.
(c) 	SIMILAR TO (b) BUT ONE PHASE SKIPPED IN THE HORIZONTAL PLANE. VERTICES OF CURVES STILL COINCIDE. A SATISFACTORY APPEARANCE RESULTS.		HORIZONTAL CURVE IS HIDDEN FROM DRIVER'S VIEW, CAUSING A DISJOINTED EFFECT.
(d) 	PROVISION OF A LONG VERTICAL CURVE COMPATIBLE WITH THE HORIZONTAL CURVE PRODUCES A SMOOTH FLOWING ALIGNMENT AND A PLEASING THREE DIMENSIONAL VIEW.		SAME AS (d) BUT THE VERTICAL CURVE IS MADE MUCH SHORTER. THOUGH THERE IS NO DISCONTI-NUITY IN PLAN OR PROFILE SINGLY, THREE DIMENSIONAL VIEW IS POOR.

FLEXIBLE PAVEMENT

4. FLEXIBLE PAVEMENT

4.1. INTRODUCTION

Pavement structure consists of the prepared subgrade and the pavement component layers such as sub-base, base and surface course. The stability or the structural capacity of the pavement depends upon the pavement layer system including the subgrade. However, the road users are concerned about the riding quality, safety and other performance aspects of the road pavement rather than the pavement structure, design life etc. Hence, it is important to ensure the above requirments also while designing a pavement. The flexible pavements are constructed as a multi-layer system consisting of typical component layers, namely sub-base, base course, and surface course.



4.1.1. EMBANKMENT AND SUBGRADE CONSTRUCTION

4.1.1.1. Embankment

Construction of embankment and preparation of subgrade are part of earth work. The main activities associated with construction are soil survey and identification of borrow area, construction of embankment and subgrade. The embankment may be constructed by rolling the earth / soil in relatively thin layers. Each layer should be compacted by suitable roller to a desired density before the next layer is placed. The height of road embankment depends on the highest flood level (HFL) in the area; generally 0.6 to 1m height above HFL or the GWL is to be ensured. Successful performance of an embankment depends as much on adopting standards of good compaction in construction as on careful pre investigations leading to selection of appropriate borrow material.

4.1.1.2 Subgrade

In Rural Roads, the top 30 cm of the cutting or embankment at the formation level shall be considered as subgrade. The subgrade should be will compacted to utilise its inherent strength and prevent permanent deformation because of additional compaction by traffic.

4.1.1.2 Specification for embankment and Subgrade

The material used in embankments, subgrades, earthen shoulders and miscellaneous backfills shall be soil, moorum, gravel, a mixture of these or any other material approved by the engineer. Such material shall be free of logs, stumps, roots, rubbish or any other ingredient likely to deteriorate or affect the stability of the embankment/ subgrade. The following material shall be considered unsuitable for embankment:

1. Materials from swamps, marshes and bogs
2. Peat, log, stump and perishable material, any soil classified as OL, OI, OH or Pt in accordance with IS: 1498
3. Materials susceptible to spontaneous combustion
4. Materials in a frozen condition
5. Clay having liquid limit exceeding 70 and plasticity index exceeding 45
6. Materials with salts resulting in leaching in the embankment
7. Expansive clay exhibiting marked swell and shrinkage properties (‘free swell index’ exceeding 50 when tested as per IS: 2720-Part 40) shall not be used as fill material. Where expansive clay with free swell index less than 50 is used as a fill material.
8. Any material with a soluble sulphate content exceeding 0.5 per cent by mass, when tested accordance with BS:1377-1975 Test 9, shall not be deposited within 500mm from concrete surface.

The size of coarse material shall ordinarily should not exceed 75 mm when placed in embankment and 50 mm when placed in subgrade. However the engineer may permit the use of coarser material if he is satisfied that the same will not present any difficulty as regards placement and compaction of fill material. The maximum particle size shall not be more than two thirds of the compacted layer thickness.

A 100% Standard Proctor Compaction should be attained in the top 30cm of the subgrade. For clayey soil, the minimum compaction for subgrade should be 95% of the Standard Proctor Compaction and the compaction should be done at moisture content 2% in excess of the optimum value. The subgrade in embankment is compacted in two layers, usually to a higher standard than the lower part of the embankment.

Where the CBR of the subgrade is less than 2% a capping layer of 100mm thickness of material with a minimum CBR of 10% or geo-textile, if found economical, is to be provided in addition to the sub-base required for CBR of 2%. If the subgrade CBR is more than 15%, there is no need to provide sub-base.

Table : 4.1. Density requirement of Embankment/ Subgrade for Rural roads (IRC SP 20 - 2002, Page No. 69)

Type of work	Maximum laboratory dry density when tested as per IS: 2720 (Part 7)
Embankments up to 3 metres height, not subjected to extensive flooding	Not less than 1.44 gm/cc
Embankments exceeding 3 metres height or embankments of any height subject to long periods of inundation	Not less than 1.52 gm/cc
Subgrade and earthen shoulders/ verges/backfill	Not less than 1.65 gm/cc

Note : (i) This Table is not applicable for lightweight fill material, e.g., cinder, fly ash, etc. for which IRC:SP:58 may be referred

ii) The Engineer may relax these requirments as his discretion taking into account the availability of materials for construction and other relevant factors.

4.1.1.3 Construction of Embankment Under Special Conditions

Specifications for construction of embankments under special conditions are given below:

(a) Embankment using coal ash

Coal ash can be used for construction of embankment of rural road projects near thermal power plants. When embankment construction is undertaken using coal ash the top soil from all areas to be covered by embankment foundation should be stripped to specified depth not exceeding 150mm and stored in stock piles of height not exceeding 2m for use in covering the coal ash embankment slopes, cut slopes and other disturbed areas where re-vegetation is desired.

(b) Earthwork for widening existing road embankment

When an existing embankment and/or subgrade is to be widened and its slopes are steeper than 1 vertical to 4 horizontal, continuous horizontal benches, each at least 300 mm wide shall be cut into the old slope for ensuring adequate bond with fresh embankment/subgrade material to be added. The material obtained from cutting of benches could be utilized in widening the embankment/subgrade. If the existing slope is flatter than 1:4, the slope surface may be ploughed or scarified instead of resorting to benching. Where the width of widened portion is insufficient to permit the use of conventional rollers, compaction can be carried out with help of small vibratory rollers/ plate compactors/power rammers.

(c) Earthwork over existing road surface

Where the embankment is to be placed over an existing road surface, the work shall be carried out depending upon pavement surface type and height of embankment. If the existing road surface is granular or bituminous pavement and lies within 1 m of the new subgrade level, the same should be scarified to a depth of 50 mm or more if specified, so as to provide ample bond between old and new material ensuring that at least 500 mm portion below the top of new subgrade level is compacted to the desired density. In case of concrete pavement, which lies within 1 m of the new subgrade level, the existing pavement should be removed completely. If the level difference between the existing road surface and the new formation level is more than 1 m, the existing surface can be permitted to stay in place without any modification

(d) Construction of embankment over soft ground

Where embankment is to be constructed over soft ground which may not support the weight of heavy construction equipment, the first layer of fill may be constructed by placing successive loads of materials in a uniformly distributed layer of minimum thickness required to support the construction equipment as permitted by the engineer. Use of suitable geo-synthetic material to increase the bearing capacity of the soil can also be made.

(e) Embankment construction in waterlogged areas

Wherever feasible, it is advisable to dewater the ponds before undertaking embankment construction. Where filling or backfilling is to be placed under water to start the construction, only acceptable granular material or rock shall be used. Acceptable granular material shall consist of graded, hard, durable particles with particle size not exceeding 75 mm. The material should be non-plastic having uniformity coefficient of not less than 10. The material placed in open water shall be deposited by end tipping without compaction.

(f) Expansive soil subgrade

Expansive soils/ Black Cotton soils are basically montmorillonitic clays which display a tendency to swell or heave during the process of wetting and to shrink when dry, as evidenced by shrinkage cracks. When subjected to seasonal wetting and drying, a road built on an expansive soil subgrade will cause unevenness of the pavement surface. In order to prevent such an unsatisfactory performance of the road, the following precautions should be taken:-

Compact the expansive soils at relatively low dry density and at high moisture content, since expansive soils compacted to high density at low moisture content will undergo higher volumetric changes. Therefore, an expansive soil should be compacted to 95% Standard Proctor compaction at a moisture content 1 to 2% higher than the optimum.

It is good practice to provide the pavement crust on an improved non-expansive soil, adequately compacted, 0.6m to 1.0 m in thickness and the pavement designed for the CBR of improved subgrade. However, where such a non-expansive buffer layer does not work out to be economical, a blanket course of coarse/ medium sand or non-plastic moorum (PI<5) or lime-treated black cotton soil subbase can be

provided, extending over the entire formation width, together with measures for efficient drainage.

4.2. SUB-BASE (Granular)

It is a layer of selected material placed on the subgrade compacted to 100% of maximum dry density for the material determined as per IS:2720 (Part 7). Generally it consists of locally available, relatively low strength inexpensive material. The principal function of sub-base is to distribute the stresses over a wider area of the subgrade imposed by traffic and to ensure that no subgrade material intrude into the base course and vice versa.

When the subgrade is silty or clayey and the annual rainfall of the area is more than 1000mm, a drainage layer of 100mm over the entire formation width should be provided.

Specification

The material to be used for this work shall be natural sand, moorum, gravel, crushed stone, or a combination thereof depending upon the grading required. Materials like crushed slag, crushed concrete, brick metal and kankar, etc. The material shall be free from organic or other deleterious material. The material shall have 9 percent fines value of 50 kN or more (for sample in soaked condition) when tested in compliance with BS: 812 (Part 3) - 1975. The water absorption of the aggregate shall be determined as per IS:2386 (Part 3)-1963 ; If this value is greater than 2 per cent, the soundness test shall be carried out on the material delivered at the site as per IS:383-1970. The CBR requirement for sub-base layer should not be less than 20 (as per IRC SP : 72 - 2007). In case the subbase material of the requisite soaked CBR value is not available within economical leads, the subbase material meeting any of the prescribed gradings and other requirements with a soaked CBR value of not less than 15 can be permitted with the approval of the competent authority. The material for sub-base shall be preferably non-plastic. Otherwise, the plasticity index (PI) of material passing 425 micron sieve shall be less than 6 and liquid limit less than 25 per cent. The material shall conform to one of the gradations specified below in Table 4.2.

Table 4.2. Gradation Requirement for Coarse Graded Granular Sub-Base (IRC SP : 20 - 2002, Page No. 70)

IS sieve Designation	Percent by weight passing the IS sieve		
	Grading I	Grading II	Grading III
75 mm	100	-	-
53 mm	-	100	-
26.5 mm	55-75	50-80	100
4.75 mm	10-30	15-35	22-45
75 micron	<10	<10	<10

Note: *The material passing 425 Micron sieve for all the three grading when tested according to IS:2720 (Part 5) shall be having liquid limit and plasticity index not more than 25 and 6 respectively.*

4.2.2 Coarse sand sub base (Drainage Layer)

The coarse to medium sand sub-base gives comparatively more effective drainage to pavement, where the embankment is clayey or black cotton soil. Sand layer shall be provided as a part of subbase over the compacted subgrade layer where annual rainfall is more than 1000 mm or CBR value less than 2. The sand layer shall normally be in 100 to 150 mm compacted thickness (necessary arrangements shall be made for local confinement of sand). The coarse to medium sand for construction of a drainage layer shall conform to given in Table 4.3

Table 4.3 Grading of coarse to medium sand for Subbase IRC SP : 20 - 2002, Page No. 188

IS Sieve	Per cent passing
11.2 mm	100
5.6 mm	80-100
2.36 mm	70-90
180 micron	<5

The sand conforming to specified grading shall be spread uniformly and evenly upon the prepared sub grade in required quantities. Immediately following the spreading of sand, watering shall be done and rolling shall be started with vibratory roller of approved type at OMC.

4.2.3. Gravel Roads

Gravel/Soil-Aggregate is natural gravel or a mix of crushed stone, crushed gravel, crushed slag, moorum, sand, fine sized particles or combination there of depending on the grading and plasticity requirements for use in base or surface course for rural roads.

Specification

The material to be used shall be graded and shall contain a fair proportion of all the particle sizes together with sufficient fines to provide proper cohesion as per technical grading limits given in Table 4.4 The compation shall be at least 100% of the maximum dry density for the material determined as per IS:2720 (Part 7). Th Liquie Limit when determined according to IS:2720 (Part 5), shall not exceed 25 and the PI shall not exceed 6.

Physical Requirments

When crushed stone/gravel/slag is used, the material shall conform to the following requirements.

(i) Wet Aggregate Impact Value (IS:5640) shall not exceed 40 and 30 when used in base and 30 when used in surfacing.

(ii) Flakiness Index (IS:2386 Part I) shall not exceed 25 percent when used in base and 20 when used in surfacing.

(iii) In high rainfall areas (annual rainfall of 1500 mm or above), coastal areas and where local soils are salt infested, if the water absorption value of the coarse aggregate is greater than 2 percent, the Soundness test shall be carried out on the material delivered to the site as per IS:2386 (Part 5).

(a) Loss with Sodium Sulphate, 5 cycles : 12 per cent maximum

(b) Loss with Magnesium Sulphate, 5 cycles : 18 per cent maximum

(iv) If crushed slag is used, Clause 405.2.5 of MORD specifications shall apply.

(v) If crushed gravel/shingle is used, not less than 90 per cent by weight of the gravel/ shingle pieces retained on 4.75 mm sieve shall have at least two fractured faces.

(vi) The needed gradation shall be obtained by crushing, screening and blending processes as necessary.

(vii) Fine aggregate material passing 4.75 mm sieve shall consist of natural or crushed sand and fine mineral particles.

Table 4.4 : Grading Requirements for Base Course

Sieve Size	Percent by Mass Passing IS Sieve Grading Designation		
	A	B	C
53 mm	100		
37.5 mm	97-100	100	
26.5 mm		97-100	100
19 mm	67-81		97-100
9.5 mm		56-70	67-79
4.75 mm	33-47	39-53	47-59
425 µ	10-19	12-21	12-21
75 µ	4-8	4-8	4-8

4.2.4. Surface course gravel/soil-aggregate : The gradation and plasticity index (PI) shall conform to the requirements given in Table 4.5

Table 4.5: Grading Requirements for Surface Course

Sieve Size	Percent by Mass Passing Designated Sieve
26.5 mm	100
19 mm	97-100
4.75 mm	41-71
425 Mi	12-28
75 Mi	9-16

4.2.5 Use of low cost alternate materials

Use of local and waste materials is always economical in construction sector. Some of these materials for sub base construction are

- Lime stabilised sub base
- Coal ash
- Slag
- Municipal waste
- Marble waste

4.3 BASE COURSE

The base course materials should be of good quality so as to withstand high stress concentrations which develop immediately under the wearing surface. Since bituminous surface consist only of a thin wearing course, the upper surface of the base must be sufficiently smooth and true to profile to provide a good riding surface.

The different types of base course which are commonly used are:

1) Water Bound Macadam (WBM)

2) Wet Mix Macadam (WMM)

3) Crusher Run Macadam Base (CRMB)

4.3.1 Water Bound Macadam (WBM)

WBM Consist of clean, crushed aggregates mechanically interlocked by rolling and bonding together with screening, binding material where necessary, and water laid on a properly prepared subgrade/sub-base/base or existing pavement, as the case may be and finished in acordance with the requirments of these Specifications and in close conformity with the lines, grades, cross-sections and thickness as per approved plans or as directed by the Engineer.

The thickness of base shall not be less than 150 mm. The grading of aggregates shall conform to requirements given in the Table 4.6 and Table 4.7.

Specification

Coarse aggregates shall be either crushed or broken stone, crushed slag, overburnt (Jhama) brick aggregates of any other naturally occuring aggregates, such as, kankar and laterite of suitable quality. Materials obtained from rocks, such as, Phyllites, Shales or Slates, etc, shall not be permitted in WBM construction. Materials other than crushed

slag shall be used in sub-base courses only. If the water absorption value of the coarse aggregate is greater than 2 per cent, the Soundness test shall be carried out on the material delivered to site as per IS:2386 (Part 5).

The coarse aggregates shall conform to one of the Gradings given in Table 4.6 as specified, provided, however, the use of Grading No.1 shall be restricted to sub-base courses only.

Table 4.6 Grading Requirements of coarse aggregates for WBM

Grading No	Size range (mm)	IS Sieve Designation (mm)	Percent by weight passing
1	90-45	125	100
		90	90-100
		63	25-60
		45	0-15
		22.4	0-5
2	63-45	90	100
		63	90-100
		53	25-75
		45	0-15
		22.4	0.5
3	53-22.4	63	100
		53	95-100
		45	65-90
		22.4	0-10
		11.2	0-5

Note : The compacted thickness for a layer with Grading 1 shall be 100 mm while for layer with other Gradings, i.e., 2 & 3, it shall be 75 mm.

4.3.1.1. Screenings (Fill Material)

Screening to fill voids in th coarse aggregate shall generally consist of the same material as the coarse aggregate. However, where economic considerations so warrant, predominantly non-plastic material (other than rouded river borne material) may be used for this pupose provided liqued limit and plasticity index of such material are below 20 and 6 respectively and fraction passing 75 micron sieve does not exceed 10 per cent. The Screenings shall not contain any of the undesirable constituents listed in 1.1.2 of the which would render it unsuitable as a fill material.

Screenings shall conform to the grading set forth in Table 4.7. The consolidated details of quantity of screenings required for various grades of stone aggregates are given in Table 4.8. The Table 4.8 also gives the quantities of materials (loose) required for $10m^2$ for base compacted thickness of 100/75 mm.

Table 4.7. Grading requirements for screening for WBM

Grading No	Size range (mm)	IS Sieve Designation (mm)	Per cent by weight passing
A	13.2	13.2	100
		11.2	95-100
		5.6	15-35
		0.180	0-10
B	11.2	11.2	100
		5.6	90-100
		0.180	15-35

The use of screenings shall be omitted in the case of soft aggregates, such as, brick metal, kankar, laterite, etc. as they are likely to get crushed to a certain extent under rollers.

4.3.1.2. Binding Material :

Binding material to be used for water bound macadam as filler material meant for preventing ravelling, shall comprise of a suitable material approved by the Engineer having a Plasticity Index (PI) value of less than 6 for sub-base/base course and 4 to 10 for surfacting course as deternmined in accordance with IS:2720

The quantity of binding materials, where it is to be used will depend on the type of screenings. Generally, the quantity required for 75 mm compacted thickness of WBM will be 0.06-0.09 cum/10 sqm. The quantity shall be in the range of 0.08- 0.10 cum/10 sqm for 100 mm compacted thickness. Table 4.8 gives the quantities of materials (loose) required for 10 sqm for subbase/base course with compacted thickness of 100 / 75 mm.

The above mentioned quantities should be taken as a guide only, for estimation of quantities for construction, etc.

Application of binding materials may not be necessary when the screenings used are of crushable type as specified in Table 4.8.

Table 4.8. Quantities required for 75 mm and 100 mm compacted WBM course.

Grading No.	Size Range (mm)	Compacted thickness (mm)	Loose quantity of Coarse Aggregate (cum)	Screenings			
				Stone screening		Crushable type, such as Moorum or Gravel (cum)	
				Size (mm)	Loose Quantity (cum)	Properties	Loose Quantity (cum)
1	90-45	100	1.21-1.43	Type A 13.2	0.27-0.30	Not uniform	0.30-0.32
2	63-45	75	0.91-1.07	Type A 13.2	0.12-0.15	Not uniform	0.22-0.24
2	63-45	75	0.91-1.07	Type B 11.2	0.20-0.22	Not uniform	0.22-0.24
3	53-22.4	75	0.91-1.07	Type B 11.2	0.18-0.21	Not uniform	0.22-0.24

The compacted thickness for a layer with Grading 1 shall be 100 mm while with grading 2 and 3 shall be 75 mm. Grading 2 and 3 shall be preferably used for construction of WBM for rural roads.

4.3.2 Wet Mix Macadam (WMM)

Wet mix macadam construction is an improvment over the conventional water bound macadam providing speedy and more durable construction. It differs from the water bound macadam in that graded aggregates and granular materials are mixed with predetermined quantity of water in accordance with the specifications to form a dense mass which is spread and rolled to approved lines, grades and cross-section to serve as pavement course(s).

Specification

WMM consists of laying and compacting clean, crushed, graded aggregate and granular material, premixed with water, to a dense mass on a prepared sub-grade/sub-base or a WBM layer. The thickness of a single compacted layer of WMM shall not be less

than 75 mm. When vibratory roller or other type of approved compacting equipment is being used, the compacted thickness of single layer may be increased up to 200 mm. The aggregates shall conform to the grading given in Table 4.9.

Table 4.9. Grading requirements for Wet Mix Macadam (WMM)

Sieve Size	Percent by Mass Passing IS Sieve Grading Designation
53.00 mm	100
45.00 mm	95-100
26.50 mm	-
22.40 mm	60-80
11.20 mm	40-60
4.75 mm	25-40
2.36 mm	15-30
600 micron	8-22
75 micron	0-8
Material finer than 425 micron shall have Plasticity Index (PI) not exceeding 6	

4.3.3 Crusher Run Macadam

This work shall consist of furnishing, placing and compacting crushed stone aggregates in accordance with the requirements of the Specification and in conformity with the lines, grades, thicknesses and cross-sections shown on the plans or as directed by the Engineer.

Specification

The material to be used for the work shall be crushed rock. If crushed gravel/ shingle is used, not less than 90 per cent by weight of the gravel/shingle pieces retained on 4.75mm sieve shall have at least two fractured faces. It shall be free from any organic matter and other deleterious substances and shall be of such nature that it can be compacted readily under watering and rolling to form a firm, stable base. The aggregate shall conform to the grading requirements shown in Table 4.10

Table 4.10. Aggregate grading requirements for CRM

Sieve size (mm)	Per cent passing by weight	
	53 mm max size	37.5 mm max size
63	100	-
45	87-100	100
22.4	50-85	90-100
5.6	25-45	35-55
0.710	10-25	10-30
0.90	2-9	2-9

At the option of the Contractor, the grading for either 53 mm maximum size or 37.5 mm maximum size shall be used, except that once a grading is selected, it shall not be changed without the Engineer's approval.

4.4. BITUMINOUS SURFACING

4.4.1 Prime Coat

Prime coat is a spray application of a single coat of low viscosity liquid bituminous material on top of the top most granular layer of the base course. Prior to applying the primer,the surface shall be carefully swept or brushed clean of dust and loose particles.

Bituminous primer should be slow setting bitumen emulsion, use of cutback being restricted to areas having subzero temperature or for emergency operations.

Specification :

Sub Section 502, Specifications for rural roads of MoRD gives details of prime coat. Bitumen emulsion shall be used as prime coat. Use of cutback bitumen should be restricted. The requirement of the prime coat for different types of base coarse is given in Table 4.11

Table 4.11 The Requirement of Viscosity and Quantity for Priming

Porosity	Type of Surface	Viscosity at 60^0 C (centistokes)	Quantity per 10 sqm. (Kg)
Low	WMM, WBM	30-60	7-10
Medium	Gravel base	70-140	9-12
High	Stabilised base	250-500	12-15

Bituminous primer shall not be applied to a wet suface or during a dust stom or when the weather is foggy, rainy or windy or when the temperature in the shade is less than 10^{o}C. Surfaces which are to receive emulsion primer should be damp, but no free or standing water shall be present.

4.4.2 Tack Coat application

Tack Coat is the application of a single coat of low viscosity liquid bituminous material to an existing bituminous road surface preparatory to the superimposition of a bituminous mix.

The binder used for tack coat shall be Rapid Setting Bitumen Emulsion Grade RS-1 complying with IS:8887. The use of cutback bitumen (Medium Curing grade) as per IS:217 shall be restricted only for sites at sub-zero temperature or for emergency applications.

Bituminous primer shall not be applied to a wet suface or during a dust stom or when the weather is foggy, rainy or windy or when the temperature in the shade is less than 10^{o}C. Where the tack coat consists of emulsion, the surface shall be slightly damp, but not wet. Where the tack coat is of cutback bitumen, the surface shall be dry.

Table 4.12 Rate of application of Emulsion for Tack Coat

Type of Surface	Quantity in kg per sq.m area
Bituminous surface	0.20 to 0.25
Dry and hungry bituminous surfaces	0.25 to 0.30
Primed granular surface	0.25 to 0.30
Unprimed granular base	0.35 to 0.40
Cement concrete pavement	0.30 to 0.35

4.4.3 Bituminous Surfacing Courses

The various types of thin bituminous surfacings may be classified into the following:

(i) Premix Carpet (PC)

(ii) Seal coat

(iii) Surface Dressing (SD)

(iv) Mixed Seal Surfacing (MSS) or Closely graded Premix Carpet

(v) Bituminous Macadam

(vi) Modified Penetration Macadam

4.4.3.1. 20 mm Thick Open-graded Premix Carpet

Open-graded Premix Carpet consist of the preparation, laying and compaction of a premix surfacing material of 20 mm thickness composeed of small-sized aggregate premixed with a bituminous binder on a previously prepared base to serve as a wearing course.

The binder shall be penetration grade bitumen of a suitable grade S-65/90, appropriate to region, traffic, rainfall and other environmental conditions satisfying the requirements of IS:73-1992. Where modified binder is specified, Subsection 512 of Specifications for rural roads of MoRD should be followed.

The PC consists of open graded coarse aggregate (0.18 m3 of size passing 20 mm and retained 10 mm sieve and 0.09 m3 of size passing 12.5 mm and retained 6.3 mm sieve for 10 m2 area), premixed with 9.5 kg and 5.1 kg bitumen respectively for 10 m2 area laid over the prepared surface with prime coat and/or tack coat

Table 4.13: Quantities of Materials Required for 10m² of Road Surface for 20 mm Thick Open-Graded Premix Surfacing using Penetration Bitumen or Cutback

Aggregates	0.18 m3
a) Nominal Stone size 13.2 mm (passing 22.4 mm sieve and retained on 11.2 mm sieve	0.09 m3
Nominal Stone size 11.2 mm (passing 13.2 mm sieve and retained on 5.6 mm sieve)	0.27 m3
Binder (quantities in terms of straight run bitumen)	
a) For 0.18 m3 of 13.2 mm nominal size stone at 52 kg bitumen per m3	9.5 kg
b) For 0.09 m3 of 11.2 mm nominal size stone at 56 kg bitumen per m3	5.1 kg
Total	14.6 kg

4.4.3.2. Seal Coat

This work shall consist of the application of a seal coat for sealing the voids in a bituminous surface laid to the specified levels, grade and cross fall (camber).

The seal coat shall be any of the three types mentioned below:

Type A : Liquid seal coat comprising of an application of layer of bituminous binder followed by a cover of stone chips.

Type B : Premixed seal coat comprising of a thin application of fine aggregate premixed with bituminous binder.

Type C : Premixed seal coat comprising of an application of 6.7 mm size stone chips premixed with bituminous binder.

Specification :

(a) Binder

The quantities required for seal coat are given in Table: 4.14

Table: 4.14. Quantities of Binder Required for Seal Coat

Type of seal coat	Per 10 sqm area	
	Bitumen in kg	Bitumen Emulsion in kg
Type A : Liquid seal coat	9.8	12 to 14
Type B : Premixed seal coat	6.8	10 to 12
Type C : Premixed seal coat using stone chips of 6.7 mm size	4.5% by weight of total mix	90 to 11

(b) Aggregates

Quantities and grading requirements for aggregates are given in Table 4.15.

Table 4.15 : Quantity and Gradation Requirement of Aggregate for Seal Coat

Type of seal coat	Quantity of aggregate required per 10 sqm area	Gradation requirement	
		100% passing sieve designation	100% retained sievedesignation
Type A	0.09 cum	11.2 mm	2.36 mm
Type B	0.06 cum	2.36 mm	180 microns
Type C	0.09 cum	9.5 mm	2.36 mm

4.3.3 Surface Dressing

This work consist of the application of one coat or two coats of surface dressing, each coat consisting of a layer of bituminous binder sprayed on a previously prepared base, followed by a cover of stone chips rolled in to form a wearing course.

One coat or two coats of surface dressing shall be decided on the basis of anticipated traffic and climatic conditions.

Surface dressing serves as a thin wearing coat, and protection against easy entry of surface water into the pavement structure for both open graded bituminous courses as well as granular pavement surface such as WBM. Surface dressing can be applied in one application (single coat) or in multiple applications (two or more coat). In two coat surface dressing first coat is laid with large size stone chippings with higher application of binder content. The smaller chippings of the second application is normally fit into the interstices between the large chippings of the first application, thus giving the combined layer much greater stability.

Specification :

Paving Bitumen shall be a suitable Penetration grade S-65/90, or as appropriate to the region, traffic and climatic conditons as directed by the Enginner. Emulsion shall be Rapid Setting Cationic type of bitumen emulsions.

The size requirments of stone chips, rates of spread for aggregates and binders per sqm and grading requirements for chips, are given in Table 4.16, 4.17 and 4.18.

Table : 4.16. Size Requirments of Stone Chips for Surface Dressing

Type of Construction	Nominal Size of Stone Chips	Specification
Single coat surface derssing or the first coat of two-coat surface dressing	13.2 mm	100 per cent passing IS sieve 22.4 mm size and retained on IS sieve 11.2 mm size
Second coat of two-coat surface dressing (also used as a renewal coat)	9.5 mm	100 per cent passing IS sieve 11.2 mm and retained on IS sieve 5.6 mm size

Table 4.17: Nominal Rates of Spread of Binder and Chips.

Nominal Chipping Size (mm)	Binder (Penetration grade bitumen) kg/m2	Bitumen emulsion (kg/m2)	Aggregate (cum/m2)
13.2	1.0	1.5	0.010
9.5	0.9	1.4	0.008
6.3	0.75	1.1	0.004

Table 4.18 Grading Requirements for Chips for Surface Dressing

IS Sieve Designation (mm)	Cumulative percent by weight of total aggregate passing for the following nominal sizes(mm)		
	13.2	**9.5**	
19.0	100	-	-
13.2	85-100	100	-
9.5	0-40	85-100	100
6.3	0-7	0-35	85-100
4.75	-	0-10	-
3.35	-	-	0-35
2.36	0-2	0-2	0-10
0.60	-	-	0-2
0.075	0-1.5	0-1.5	0-1.5
Minimum 65% by weight of aggregate	Passing 13.2 mm retained 3.35 mm	Passing 9.5 mm retained 9.5 mm	Passing 6.3 mm retained 6.3 mm

4.4.3.4. Mix Seal Surfacing

This work shall consist of the preparation, laying and compaction of mix seal surfacing material of 20 mm thickness composed of graded aggregates premixed with a bituminous binder on a previously prepared surface, in accordance with the requirements of these Specifications, to serve as a wearing course. No Mix Seal Surfacing layer shall, however, be placed directly over WBM base.

Mix seal surfacing shall be of Type A or Type B as specified in the Contract documents.

Specificaton :

The binder shall be penetration grade bitumen of a suitable grade, appropriate to region, traffic, rainfall and other environmental conditions satisfying the requirements of IS:73-1992. Where modified binder is specified, Subsection 512 of Specifications for rural roads of MoRD should be followed.

The total quantity of aggregate for Type A or Type B close-graded premix surfacing shall be 0.27 cum per 10 sqm area. The quantity of binder shall be 22 kg and 19 kg per 10 sqm area for Type A and Type B Mix Seal Surfacing respectively.

The combined coarse and fine aggregates shall conform to one of the gradings given in Table. 4.19

Table: 4.19. Aggregate Gradation for Mix Seal Surfacing

IS sieve designation (mm)	Cumulative percent by weight passing	
	Type A	Type B
13.2	—	100
11.2	100	88 -100
5.6	52 -88	31 -52
2.8	14 -38	5 -25
0.090	0 -5	0 -5

4.4.3.5 Bituminous Macadam

This work shall consist of construction in a single course having 50 mm to 75 mm thickness of compacted crushed aggregates premixed with a bituminous binder on a previously prepared base.

The binder content shall be in between 3.1 to 3.5 percent depending upon the type of aggregate. The layer of bituminous macadam shall be covered with wearing coat or subsequent layer within 48 hours. If there is any delay, surface may be covered by sand seal.

Specification :

The aggregate of different sizes shall be proportioned and blended to produce a uniform mixture in accordance with IS:2386 (Part 1) (wet sieving method).

The bitumen shall be of paving grade conforming to IS: 73-1992, Where modified binder is specified, Subsection 512 of Specifications for rural roads of MoRD should be followed. The choice of bitumen to be selected depending on the maximum and minimum annual temperatures in the area.

Table 4.20: Composition of Bituminous Macadam

IS Sieve (mm)	Cumulative Per cent Passing by weight of Total Aggregate
26.5	100
19	90-100
13.2	56-88
4.75	16-36
2.36	4-19
0.03	2-10
0.075	0-5
Bitumen content, % by weight of total mixture	3.3-3.5
Bitumen penetration Grade	35 to 90

90 per cent by weight of the crushed material retained on the 4.75 mm sieve shall have at least two fractured faces.

Fine agregates shall consist of crushed material, passing 2.36 mm sieve and retained on 75 micron sieve.

4.4.3.6 Modified Penetration Macadam (MPM)

The work shall consist of construction of one or more layers of compacted coarse aggregates (in accordance with the requirments of these Specificatons to be used as a base course on roads) with alternate applications of binder and key aggregates. Thickness of an individual course shall be 50 mm or 75 mm.

It is applied when a thin premix carpet (20-25 mm) laid directly on granular surface gets deteriorated fast if the traffic is reasonably high. Thicker treatments, like DBM and BM are costly and for level of traffic on rural roads does not justify the same. Therefore, it is essential to have transition/intermediate layer like penetration macadam, modified penetration macadam and built up spray grout. Built up spray grout involves use of mechanically crushed metal. However, the requirement of the

crushed metal is reduced in the case of penetration macadam and modified penetration macadam, and also cost effective. In such a situation, it is desirable to replace the top layer of WBM by one layer of MPM.

Specification :

The material is similar to WBM except that some key aggregates and lean dose of bitumen replace the moorum and water. In this treatment, 40 mm hand broken metal is used. Though hand broken metal is perferred about 30 per cent quantity can be replaced with 40 mm crusher broken metal. The gradation for 40 mm metal has to conform to 100 per cent passing 50 mm sieve and fully retained on 25 mm sieve. Also, 12 mm size key aggregates are used. The gradation for 12 mm metal has to conform to 100 per cent passing 20 mm sieve and fully retained on 10 mm sieve. Bitumen of 30/40 (S-35) or 60/70 (S-65) penetration grade can be used grouting. The selection of the grade of bitumen shall depend upon the climatic condition, traffic intensity, etc.,

Table 4.21 : Grading requirements of coarse aggregates and key aggregates for Bituminous Penetration Macadam

IS sieve designation	Per cent by weight passing the sieve			
	For 50 mm compacted thickness		For 75 mm compacted thickness	
	Coarse Aggregate	Key Aggregate	Coarse Aggregate	Key Aggregate
63 mm	-	-	100	-
45 mm	100	-	58-82	-
26.5 mm	37-72	-	-	100
22.4 mm	-	100	5-27	50-75
13.2 mm	-	-	-	5-25
11.2 mm	-	-	-	5-25
5.6 mm	-	5-25	-	-
2.8 mm	0-5	0-5	0-5	0-5

Table 4.22. Rate of Application of Aggregate Per 10 Sqm Area (Table 500.7 MoRD, Specification for Rural Roads, 2004 Page No. 170)

Description	Thickness of Modified Penetration Macadam layer			
	75 mm		50 mm	
	On Bituminous surface(cum)	On WBM surface(cum)	On Bituminous surface(cum)	On WBM surface (cum)
40 mm size hand broken metal	0.90	0.90	0.6	0.6
12 mm size stone chips	0.18	0.18	0.18	0.18

Table 4.23. Rate of Application of Bitumen Per 10 Sqm Area

Description	Thickness of Modified Penetration Macadam layer			
	75 mm		50 mm	
	On Bituminous surface(cum)	On WBM surface(cum)	On Bituminous surface(cum)	On WBM surface (cum)
Bitumen for grouting	20	20	17.50	17.50
Tack Coat	As per 4.12			

FLEXIBLE PAVEMENT DESIGN

5. Flexible Pavement Design

5.1. INTRODUCTION

The road structure may be divided into four major components, viz., land, earthwork, pavement and cross drainage works. The pavement constitutes nearly one-third to one-half of the total cost of the road. Therefore, very careful consideration should be there for the choice of the type of pavement and its design.

5.2.1. Objectives of pavement design:

1. To provide a stable surface under wheel loads
2. To provide good riding surface
3. To have durability
4. To have cost effectiveness

5.2.2. Requirements of Pavements:

1. Stable, Non-yielding surface
2. Limited elastic deformation
3. Least rolling resistance
4. Smooth riding surface
5. Transfer stresses over a wider area on soil subgrade
6. Capillarity arrest

5.2.3. The factors which govern the selection of the type of the pavement are:

1. Initial (construction) cost
2. Availability of good materials locally
3. Cost of maintenance or rehabilitation during service
4. Technology of construction required and its availability

5.3. Recommended design approach for the design of Rural Roads

For purposes of pavement structural design, the low volume rural roads are divided into the following categories:

a) Gravel/Aggregate-surfaced roads (Unpaved Roads);

b) Flexible Pavements (Paved Roads); and

c) Rigid Pavements

The international experiences, for the past several decades, with gravel roads notably in the USA show that the maximum traffic level upto 100,000 Equivalant Standard Axle Load (ESAL) applications can be considered for Gravel Roads, while the practical minimum level (during a single performance period) is 10,000. Below ESAL applications of 10,000, even Earthern Roads are suitable.

Gravel is defined as a mix of stone, sand and fine-sized particles used as a sub-base, base or surfacing on a road, the material specifications for use in these layers being available in Clauses 401 and 402 of the MORD specifications for rural roads. When the required gradation of gravel is not available in a natural form, the blending of naturally occurring materials in the required proportions may be resorted to.

For low volume rural roads, still carrying a sizable volume of truck and bus traffic, the maximum number of ESAL applications considered for flexible or rigid pavement is upto 1 million ESAL applications. The practical minimum traffic level for a flexible or rigid pavement is about 50,000 ESAL applications during a single performance period.

The Serviceability rating system from 5 to 1 as per the PMGSY Operations Manual 2005(in terms of Present Serviceability/Condition Index) has been adopted. For the low volume rural roads in India, a Terminal Serviceability Index (i.e., the lowest index that will be tolerated before rehabilitation / strengthening or reconstruction becomes necessary) of 2.0 is considered suitable. The thickness of gravel / aggregate – surface roads (unpaved roads) has been based on the following criteria:

i. The serviceability loss over the design life is limited to 2.0, taking the initial serviceability index to be 4.0 just before opening the road to traffic, and the

terminal serviceability of 2.0 when rehabilitation will be due, with or without provision of an overlay.

ii. The allowable depth of rutting under 3m straight edge does not generally exceed 50 mm.

The design traffic parameter has been expressed in terms of the cumulative 80 kN (8.16 tonnes) ESAL applications during the design life. Seasonal variations by way of enhanced traffic during the harvesting seasons have also been considered. For the evaluation of the subgrade strength for new roads, the selection of moisture content has been dealt with scientifically instead of always insisting on 4-day soaked CBR values. For the rehabilitation or upgradation of existing rural roads, the use of Dynamic Cone Penetrometer (DCP) (mm/blow) has also been recommended for insitu subgrade strength evaluation.

5.3.1. THE DESIGN PROCESS

5.3.1.1. New roads

5.3.1.1.1 Estimation of traffic

Where no road is existing at present, the estimation of the amount of traffic over the design life cannot be made directly on the basis of traffic counts. In such cases, it would be most expedient to carry out traffic counts on an existing road, preferably in the vicinity with similar conditions. Based on such traffic counts on an existing road catering to a known population and known amount of agricultural/ industrial produce, the amount of traffic expected to ply on the new road can be suitably worked out.

5.3.1.1.2. Assessment of the subgrade strength

It is necessary to scientifically carry out a soil survey and test the representative samples for standard IS classification tests, compaction tests and CBR. The depth of the Ground Water Table (GWT) and its fluctuations, annual rainfall, and other environmental conditions that influence the subgrade strength must be investigated. During the soil survey, it must be ensured that even if the same soil type continues, at least three samples must be collected per kilometer length, for soil classification tests. The entire length must be divided into uniform sections based on soil classification

and Ground Water conditions. On each soil type, compaction and CBR tests shall be carried out to determine the strength of the subgrade soil for design purposes. A simple procedure for estimating CBR value of subgrade soil on the basis of soil properties is also suggested.

5.3.1.1.3. Determination of pavement thickness and composition

It is necessary to carry out a comprehensive field materials survey and the needed laboratory tests on representative samples to maximize the use of locally available materials for use in sub-base, base and surface courses as such or after suitable blending.

5.3.1.2. Upgradation/rehabilitation of existing roads

5.3.1.2.1. Traffic parameter

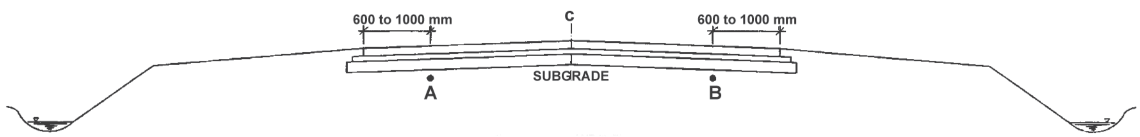
The amount of traffic expected to ply over the future design life of the existing road can be based on actual traffic counts on the existing road. These traffic counts shall be carried out both during the lean non-harvesting season and also during the peak harvesting seasons. The cumulative traffic repetitions over the design life can be calculated considering the growth rate as per the potential in the area for generating traffic.

5.3.1.2.2 Subgrade strength

For the upgradation/ rehabilitation of an existing road, the subgrade strength will be determined by carrying out CBR test on a representative sample of subgrade soil remoulded to the field density and at the field moisture content, determined after the recession of monsoon. If, however, it is not found possible to determine the field moisture content immediately after the recession of monsoon, the subgrade strength shall be determined by the 4 days soaked CBR test on a representative soil sample, compacted to field density in order to simulate the worst moisture condition.

Alternatively, the subgrade strength can be determined by carrying out DCP tests and interpolating CBR value from the DCP – CBR relationship graph as shown below.

DCP test can be determined at every 250 m in the subgrade at a distance of about 0.6 m to 1.0 m from the carriage way at the subgrade level in a staggered manner on each side of the carriageway. In case the subgrade soil contains gravel or stone particles of size exceeding 20 mm, or if repeated DCP tests carried out in a stretch of one km give results varying by more than one-third of the average value, it is desirable to carry out soaked CBR test on remoulded soil specimens compacted at field dry density as per IRC guidelines.



INSITU SUBGRADE STRENGTH DETERMINED AT 'A' AND 'B' EITHER IN TERMS OF DCP VALUES OR IN TERMS OF CBR ON SAMPLES REMOULDED TO THE INSITU DENSITY AT THE FIELD EQUILIBRIUM MOISTURE CONTENT

5.3.2. DYNAMIC CONE PENETROMETER TEST

The Dynamic Cone Penetrometer is a simple device developed in UK for rapid in-situ strength evaluation of subgrade and other unbound pavement layers. Essentially, DCP measures the penetration of a standard cone when driven by a standard force, the reported DCP value being in terms of the penetration of the standard cone, in mm per blow shows a typical DCP, The standard steel cone with an angle of 60^{o} has a diameter of 20 mm. The standard 8 kg drop hammer slides over a 16 mm dia steel rod with a fall height of 575 mm.

Basically, the penetration (in mm) per blow is inversely proportional to the strength of the material. Thus, higher the CBR value of a material being tested, lower will be the DCP value in mm/below. Besides the measurement of subgrade strength, the DCP tests can be conducted to determine the boundaries between pavement layers with different strengths and their thickness. The measurements can be taken upto 1.2 m depth with an extension rod.

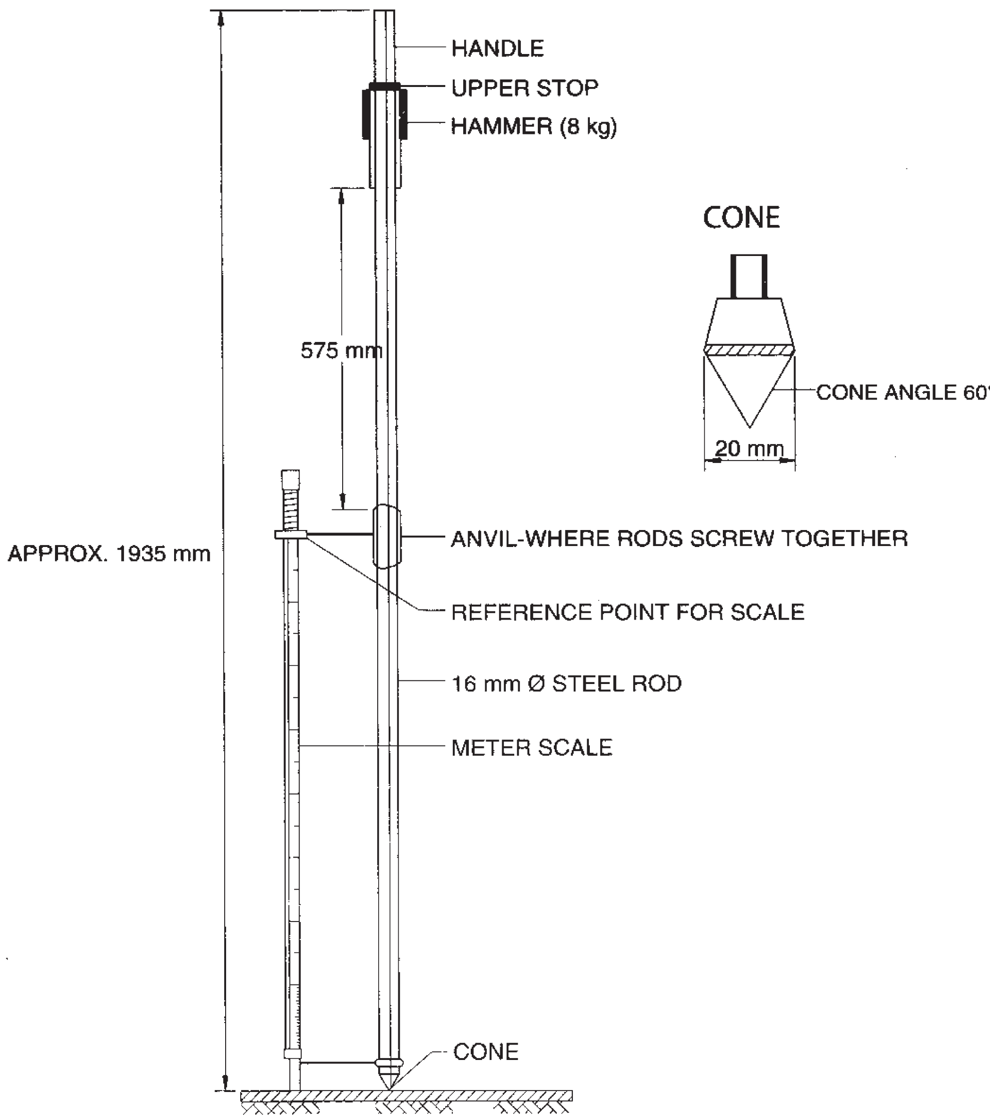
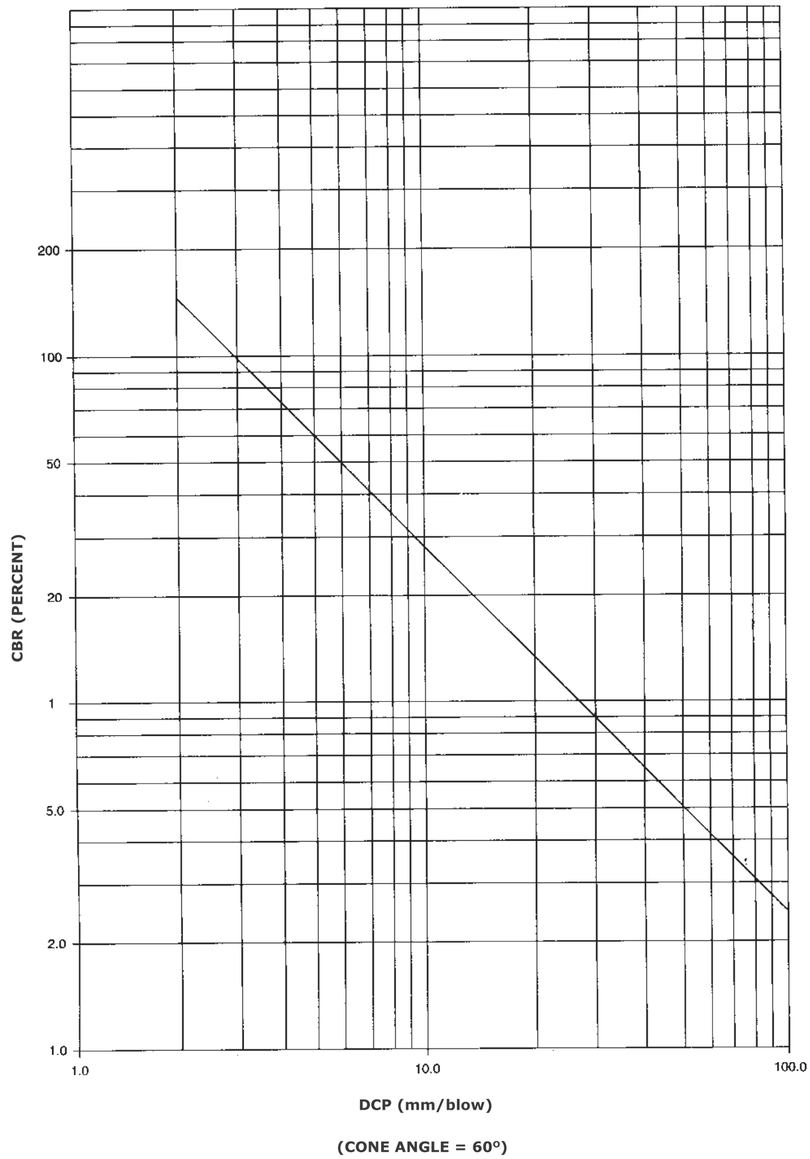


Fig : 5.1. A Typical Dynamic Cone penetrometer (DCP)

While one person holds the DCP instrument in a vertical position, another person carefully drops the weight and the third takes the readings of penetration. The penetration of the cone can be measured on a graduated scale. The readings are taken with each blow of the weight. The field data is reduced in terms of penetration versus corresponding number of blows. The number of blows and depth readings are recorded on the Dynamic Cone Penetrometer Test sheet. The cone is case – hardened but requires replacing. When used on subgrade materials the cone can be expected to last 30 to 40 tests before replacement.

The DCP test is specially useful for bituminous pavement rehabilitation design and is being used extensively in several countries.



DCP-CBR Relationship

5.3.3. Overlay thickness requirement

The causes of poor condition of the pavement should first be determined from the data collected on the existing road. Many times, the poor performance is due to lack of proper drainage or lack of lateral support from the shoulders etc. in such cases, these deficiencies must be made up without resorting to any strengthening measures. If, however, from the design catalogues, it is found that the total pavement thickness requirement, determined from the existing subgrade strength and for the future growth of traffic during the design life, is more than the existing pavement

thickness, then an overlay is to be provided. The thickness of the overlay and properties of the material to be used in the overlay can be determined from the design catalogue.

For purposes of pavement design, the large number of bicycles, motor cycles and pneumatic tyred animal drawn carts are of little consequence and only the motorized commercial vehicles of gross laden weight of 3 tonnes and above (i.e. HCV and MCV) are to be considered.

5.4 FACTORS GOVERNING PAVEMENT THICKNESS AND COMPOSITION

5.4.1 General

A hard pavement crust is provided over the subgrade so as to keep the deformation at the pavement surface within the specified tolerable limits. The parameters that guide the thickness and composition requirements for a flexible pavement are :

- Traffic, its volume and composition
- Strength of the subgrade soil

5.4.2. Traffic Parameter

5.4.2.1. Traffic growth rate

Trend analysis

The past trend of growth is analysed and the rate established by fitting a relationship of the type $T_n = T_0(1+r)^n$ where 'n' is the number of years. T_0 is the traffic in zero year, T_n is the traffic in the n^{th} year and 'r' is the rate of traffic growth in decimals. The future rate of growth can be fixed equal to or higher than the past rate depending on socio-economic considerations and future growth potential of the region where the road is located. Local enquiries in this regard are often very useful.

Recommended growth rate

In the absence of any specific information available to the designer, it is recommended that an average annual growth rate of 6% over the design life may be adopted.

5.4.3. Design life

A design life of 10 years is recommended for purposes of pavement design for gravel roads (with periodic regravelling) and for flexible pavements. This design life period of 10 years has been recommended to ensure that neither the strengthening will need to be carried out too soon nor will the design for a very long design period be unduly expensive by way of high initial investment required.

5.4.4. Computation of design traffic

5.4.4.1. For upgradation of existing road

i. Traffic census should be conducted over a period of at least 3 days, both during the peak harvesting season and also during the lean season for various vehicle types, both motorised as well as non-motorised; the number of laden, unladen and overloaded commercial vehicles also to be recorded during the traffic counts. Traffic census will be carried out during one of the harvesting seasons and also during the lean season. The average duration of each harvesting and likely change in the peak traffic during other harvesting seasons than the one during which the census has been taken shall be ascertained from local enquiries and suitably considered in estimation of traffic. In case any information regarding change in peak traffic during other harvesting seasons could not be ascertained through local enquiries, the traffic could be assumed to be the same as the traffic data collected during the harvesting season.

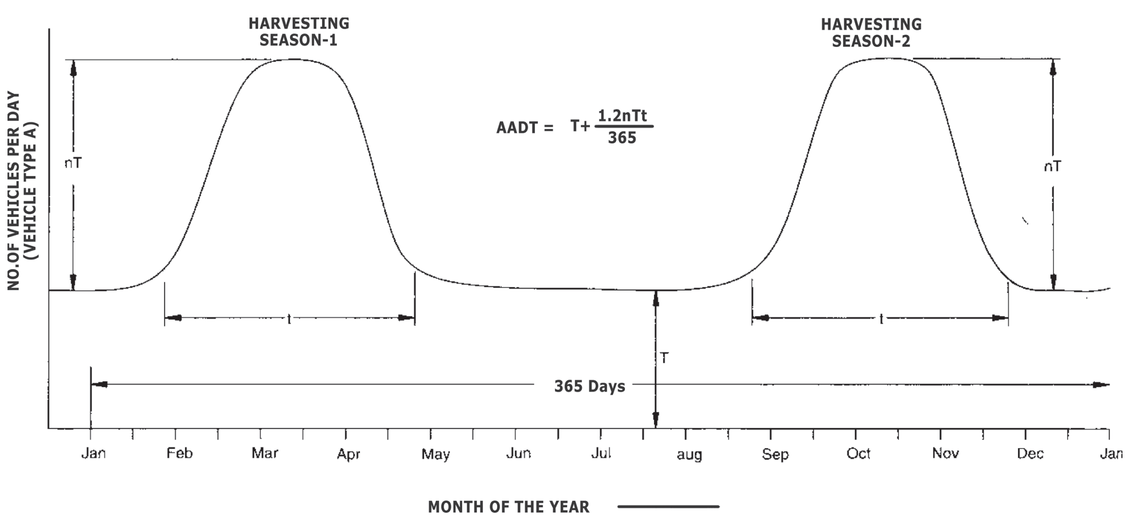


Fig.5.2 Seasonal Variations in Rural Traffic

ii. Average daily traffic (ADT) for 24 hours should be computed for each vehicle type, both during the peak harvesting season and also during the lean harvesting season. Knowing the duration of harvesting season, (Fig.5.2) the total traffic during the year can be computed and consequently the Average Annual Daily Traffic (AADT) can be computed for each vehicle type.

Although the number and duration of harvesting seasons can vary from one region to the other, typically two harvesting seasons during the course of a year are shown in Fig.1. If it is the average number of commercial vehicles of a given category, moving per day during the lean season, the enhanced traffic during the peak season can be denoted by nT, over and above the lean season traffic T, the value of n varying widely from one region to the other. Typically, it takes about 40% of the duration of a harvesting season (t) to build up the traffic from lean season level T to the peak. The Peak Traffic may continue for about 20% of the duration of harvesting period before coming down to the lean season traffic level over a period of time, against about 40% of the total duration of the harvesting season. With these assumptions, the total number of repetitions (N) of a given vehicle type during the course of a year is given by:

$N = T \times 365 + 2nT\,[0.6\,t]$

Average Annual Daily Traffic (AADT)

$= T + (1.2nTt/365)$

5.4.4.2. New road

In case of a new road, an approximate estimate should be made of traffic that would ply on the road considering the number of villages and their population along the road alignment and other socio-economic parameters. Traffic counts can be carried out on an existing road in the vicinity with similar conditions and knowing the population served as well as agricultural/ industrial produce to be transported, the expected traffic on the new proposed road can be estimated.

Determination of ESAL applications

For purpose of pavement design, only commercial vehicles with a gross laden weight of 3 tonnes or more along their axle loading are considered. These may include inter alia the following:

I. Trucks (Heavy, Medium)

II. Buses

III. Tractor-Trailers

The traffic parameter is generally evaluated in terms of a Standard Axle Load of 80 kN and the cumulative repetitions of the Equivalent Standard Axle Loads (ESAL) are calculated over the design life. Rural vehicles with single axle loads different from 80 kN, can be converted into standard axles using the Axle Equivalency Factor.

Axle Equivalency factor = $(W/Ws)^4$

Where W = Single axle load (in kN) of the rural vehicle in question

Ws = Single axle load of 80 kN

The Equivalency Factors for converting to the Standard Axle Load of 80 kN are given below:

Axle load		Equivalency Factor
(Tonnes)	kN	
3.0	29.4	0.02
4.0	39.2	0.06
5.0	49.1	0.14
6.0	58.8	0.29
7.0	68.7	0.54
8.0	78.5	0.92
9.0	88.3	1.48
10.0	98.1	2.25
11.0	107.9	3.30
12.0	117.7	4.70
13.0	127.5	6.40
14.0	137.3	8.66
15.0	147.1	11.42

The design traffic is considered in terms of cumulative number of Standard Axles to be carried during the design life of the road.

For single-lane and intermediate lane roads, the design shall be based on the total number of commercial vehicles per day in both directions. For double-lane roads, the design should be based on 75% of the total number of vehicles in both the directions.

5.4.4.3. Vehicle damage factor

The Vehicle Damage Factor (VDF) is a multiplier for converting the number of commercial vehicles of different axle loads to the number of standard axle load repetitions. It is defined as "equivalent number of standard axles per commercial vehicles".

Towards the computation of ESAL applications, the indicative VDF values (i.e, Standard Axles per Commercial Vehicle) are given below:

Vehicle Type	Laden	Unladen/ Partially Laden
HCV	2.86	0.31
MCV	0.34	0.02

Assuming a uniform traffic growth rate *r* of 6% over the design life (n) of 10 years, the cumulative ESAL applications (N) over the design life can be computed using the following formula:

N = To x 4811 x L

Where,

To= ESAL per day = number of commercial vehicles per day in the year of opening x VDF

And L= lane distribution factor = 1 for single lane/intermediate lane

And L= 0.75 for two-lane roads

Traffic categories

For pavement design, the traffic has been categorized into seven categories as under

Traffic Category	Cumulative ESAL Applications
T1	10,000-30,000
T2	30,000-60,000
T3	60,000-100,000
T4	100,000-200,000
T5	200,000-300,000
T6	300,000-600,000
T7	600,000-1,000,000

5.4.5. Subgrade Strength Evaluation

5.4.5.1. Subgrade strength

5.4.5.1.1. Design for new roads

For the pavement design of new roads, the subgrade strength needs to be evaluated in terms of CBR value.

The CBR of the subgrade can be estimated by any of the following methods:

(i) Based on soil classification tests and using Table 5.1 which gives typical presumptive design CBR values for soil samples compacted to proctor density at optimum moisture content and soaked under water for 4 days.

(ii) Using nomograph (Fig.5.3) based on wet sieve analysis data, for estimating 4-days soaked CBR values on samples compacted to proctor density.

(iii) Using two sets of equations as given below, based on classification test data, one for plastic soils and other for non-plastic soils, for estimating soaked CBR values on samples compacted to proctor density.

(iv) By conducting actual CBR tests in the laboratory.

The CBR should be conducted on representative samples of subgrade soil compacted by static compaction to 100% Standard Proctor dry density and tested at a moisture content corresponding to the wettest moisture condition likely to occur in the subgrade during its service life. An average of test values obtained from a set of 3 specimens should be reported. If the high variations are observed in the test averages, then an average of test values obtained from 6 specimens should be taken.

Table 5.1. Typical Presumptive Design CBR Values

Description	IS Soil Classification	Typical Soaked CBR Value(%)
Highly Plastic Clays and Silts	CH,MH	*2-3
Silty Clays and Sandy Clays	ML, MI, CL, CI	4-5
Clayey Sands and Silty Sand	SC, SM	6-10

***** Expansive clays like BC Soil may have a soaked CBR of less than 2%

Quick Estimation of CBR

Plastic Soil

CBR = 75/(1+0.728 WPI)

Where WPI = Weighted Plasticity Index = $P_{0.075}$ x PI

$P_{0.075}$ = % Passing 0.075 mm sieve in decimal

PI = Plasticity Index of the Soil in %.

Non-Plastic Soil

CBR = 28.091 $(D_{60})^{0.3581}$

Where D_{60} = Diameter in mm of the grain size corresponding to 60% finer.

Soil classification can be used for preliminary report preparation.

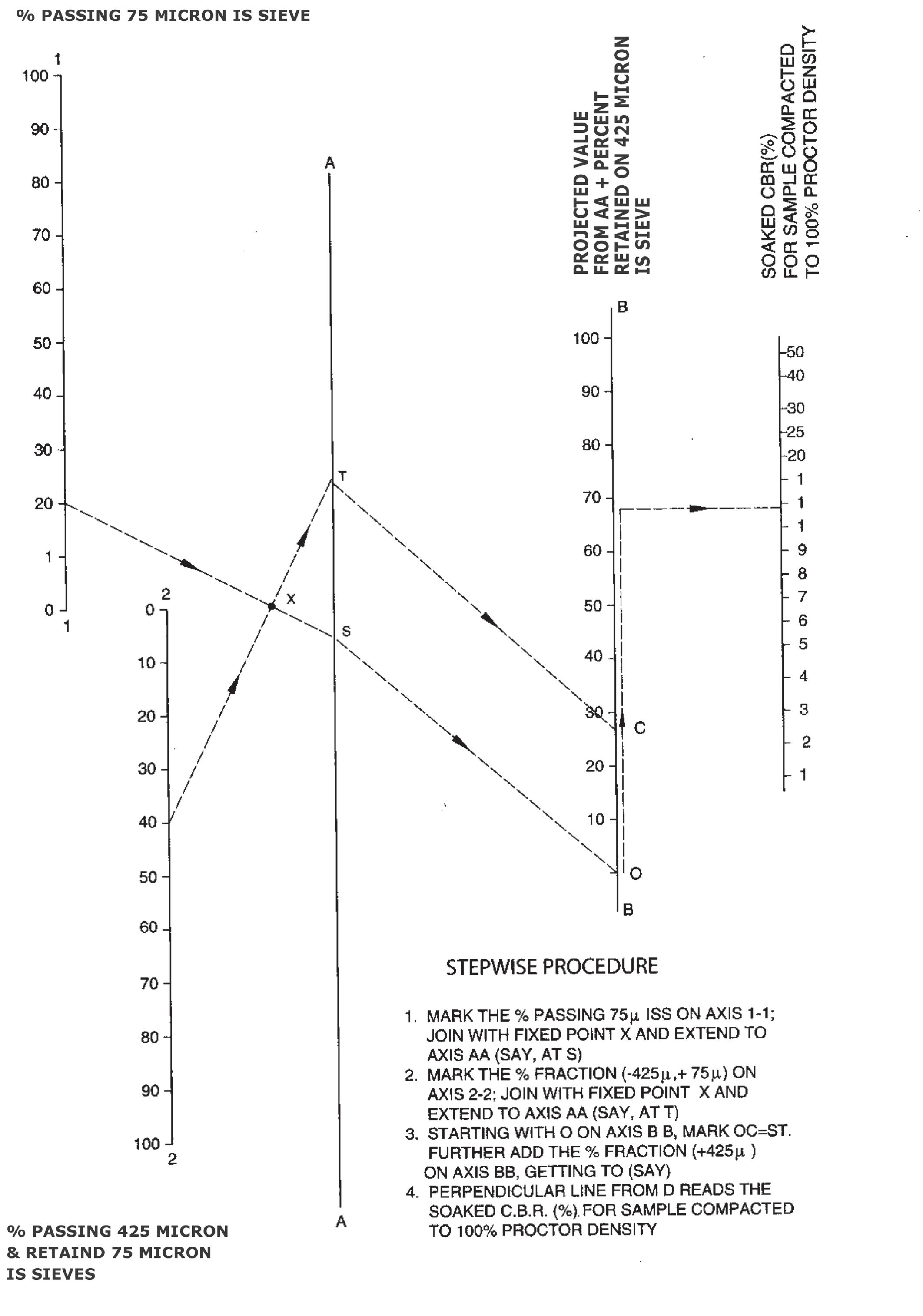


Fig. 5.3. Nomograph for Computing Soaked CBR Value from Sieve Analysis Data

5.4.5.2 Subgrade Strength Classes

In order to use the design Catalogue the subgrade strength is divided into the following classes:

Quality of Subgrade	Class	Range (CBR %)
Very Poor	S1	2
Poor	S2	3 - 4
Fair	S3	5 - 6
Good	S4	7 - 9
Very Good	S5	10 - 15

5.4.6. Selection of moisture content for subgrade strength evaluation:

The subgrade moisture conditions can be classified as under:-

Subgrade Classification	Estimating Subgrade Moisture Content
1) Where the GWT is close enough to the ground surface to influence the subgrade moisture content. In non plastic soils, GWT will influence the subgrade moisture content, if it rises to within 1 m of the road surface; in clays of low plasticity (PI <20), if GWT rises within 3 m of the road surface and in heavy clays (PI>40), if GWT rises within 7m of the road surface. This category also includes coastal areas and flood plains where the GWT is maintained by the sea, by a lake or by a river, besides areas where GWT is maintained by rainfall.	1) The most direct method is to measure the moisture content in subgrade below existing pavements in similar situations at the time of the year when the GWT is at its highest level. 2) The subgrade moisture content for different soil types can be estimated by using the ratio $\frac{\text{Subgrade Moisture Contents}}{\text{Plastic Limit}}$ which is about the same when GWT and climatic conditions are similar 3) Where such measurements are not possible, subgrade strength may be determined in terms of 4 days soaked CBR Value
2) Subgrades with deep GWT but where seasonal rainfall brings about significant changes in moisture conditions under the road.	1) The subgrade moisture condition will depend on the balance between the water entering the subgrade through pavement edges/shoulders during rains and the moisture leaving the ground during dry periods. The design moisture content can be taken as optimum moisture content obtained from Proctor Compaction Test IS 2720 (Part 7) corresponding to maximum dry density or from the nomograph given in Fig 5.3 whichever is higher. 2)The possibility of local perched GWT and effects of seasonal flooding should, however also be considered while deciding of GWT depth. Where such situations are encountered, the subgrade strength may be determined in terms of 4- day soaked CBR value.

5.5. PAVEMENT COMPOSITION AND MAXIMISING USE OF LOCALLY AVAILABLE MATERIALS

5.5.1 Pavement Composition

5.5.1.1.Sub-base course:

For granular sub-base, the materials generally used are natural sand, moorum, gravel, crushed slag, brick metal, kankar or combination thereof depending upon the grading required as per Clause 401 of the MORD Specification for Rural Roads. For silty clays and clayey soils including Black-Cotton soils, a lime treated subbase may be provided as per Clause 403 of the MORD Specifications for Rural Roads, taking care that the lime shall have purity of not less than 70% by weight of quicklime (CaO) when tested in accordance with IS 1514. Where the lime of different Calcium Oxide content is to be used, its quantity should be suitably adjusted so that equivalent Calcium oxide content is incorporated in the work. For soils which do not respond to lime treatment and where comparatively higher and faster development of strength and durability characteristics are needed, especially for waterlogged and high rainfall areas, cement treated subbase course can be provided, as per Clause 404 of the MORD Specification for Rural Roads. The cement content for a cement treated subbase should be determined by mix design, yielding a 7-day unconfined compressive strength of not less than 1.7 Mpa. From practical consideration, the thickness of subbase, where provided, shall not be less than 100mm.

5.5.1.2.Base Course

For rural roads designed for cumulative ESAL repetition of more than 1,00,000, unbound granular base which comprise conventional Water Bound Macadam(WBM), Wet Mix Macadam(WMM) or Crusher Run Macadam Base(CRMB) are adopted as per Clauses 405, 406 and 411 of the MORD Specifications for Rural Roads. Where hard stone metal is not available within economical leads, a cement stabilized base can be provided as per Clause 404 of the MORD Specifications of Rural Roads.

For rural roads designed for Cumulative ESAL repetition less than 1,00,000, a Gravel base is recommended, except for a very poor subgrade strength(CBR=2) under the traffic categories of 30,000 to 60,000; and 60,000 to 1,00,000 ESAL applications for a poor subgrade strength(CBR=3 to 4) under the traffic categories of

60,000 to 1,00,000 ESAL applications. The various grading, plasticity and other requirements for a Gravel base are detailed in Clause 402 of the MoRD Specification for Rural Roads.

5.5.1.3.Surfacing:

For rural roads designed for cumulative ESAL repetition over 1,00,000, a bituminous surface treatment of 2-coat surface dressing or 20mm premix carpet is recommended as per MORD Specification for Rural Roads. However for rural roads designed for ESAL application less than 1,00,000 a non bituminous gravel surfacing is recommended as per Clause 402 of the MORD Specification for Rural Roads, except for the very poor subgrade strength (CBR=2) under traffic categories T2 to T3 and for poor subgrade strength (CBR=3 to 4) under traffic category T3 only, where a bituminous surface treatment has been recommended.

5.5.2.Maximizing Use of Locally Available Materials:

The locally available material can be grouped under following categories:

i) Selected granular soil for use in subgrade

ii) Mechanical stabilisation, stabilisation with lime, cement, lime and fly ash, as appropriate

iii) Naturally occurring softer aggregate like moorum, kankar,gravel etc.

iv) Brick and overburnt brick metal

v) Stone metal

vi) Industrial wastes

Maximizing the use of locally available materials, suitable and economical designs can be worked out and most suitable and economical design adopted.

5.6. PAVEMENT DESIGN OF GRAVEL /SOIL AGGREGATE ROAD

Gravel/Soil-Aggregate is a mix of stone, sand and fine-sized particles used as subbase, base or surfacing on a road. The gradation and plasticity requirements for

us in subbase, base and surfacing are given in Clauses 401 and 402 of the MORD Specifications for Rural Roads. The required properties of road gravels may or may not be available in naturally occurring gravels. The aggregate gradation can be obtained by crushing, screening and blending process as may be necessary. Fine aggregate, passing ISS 4.75mm consists of natural or crushed sand and fine mineral particles. The physical requirements of fine aggregates are given in Clause 402 of the MORD Specifications for Rural Roads.

For gravel roads when the subgrade CBR is above 2, the traffic level considered is upto 60,000 repetitions of 80kN ESAL. However when the subgrade CBR is above 5, a gravel/aggregate-surfaced road can take upto 1,00,000 ESAL applications during the design life.

It is to be recognized that Gravel or Aggregate-surfaced roads can serve low volume traffic for many years provided they are well maintained, by regularly replenishing lost gravel and periodic regravelling. These roads are relatively much easier to maintain compared to black top roads involving a much lower level of resources, skills and equipment. Essentially, the maintenance measures are aimed at repairing the damage caused by combined effects of weather and traffic and to provide the desired level of serviceability by performing the following maintenance tasks:

a) Grading to restore a good cross profile to enable water to be drained off and to restore gravel from the shoulders to fill up pot holes and corrugation.

b) Dragging, to correct minor defect on the road surface using a tractor towed drag.

c) Patching of pot holes can be carried out by manual methods.

d) Regravelling before surface starts deteriorating rapidly using only agricultural tractors and manual labours. Regravelling may be justified periodically say every 3 to 5 years depending on traffic and climatic conditions.

e) Dust control by using surface gravel with relatively higher percentage of fines as per Clause 402 of MORD Specifications for rural roads. In arid and semi arid areas it may be necessary to periodically spread natural clay or to spray hygroscopic products like low cost chlorides of calcium, Magnesium or Sodium.

Thin bituminous surface treatment as dust pallaiative may also be considered if the above suggested method is not practicable.

5.6.1 Design Chart

The gravel base thickness required for the five subgrade strength classes (S1, S2, S3, S4, and S5) and for the traffic categories of cumulative ESAL repetitions 10,000-30,000 (T1); 30,000-60,000 (T2) and 60,000-100,000 (T3) are shown in Fig. 5.4. A chart to convert a portion of the Aggregate Base Layer thickness to an equivalent thickness of subbase with an intermediate CBR value between the base and subgrade is shown in Fig. 5.5.

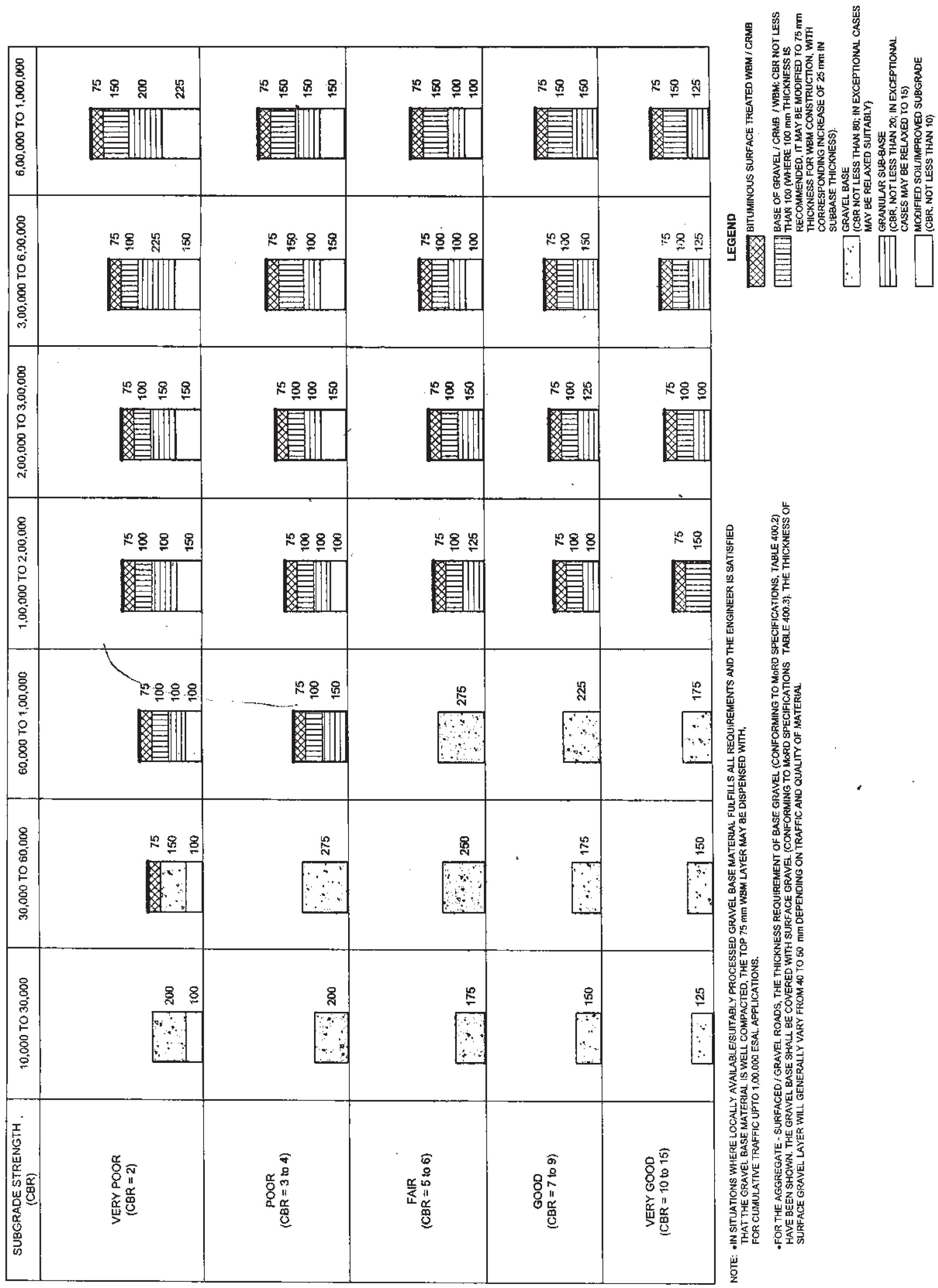


Fig 5.4. Pavement Design Catalogues

Example:

Initial Base Thickness DBSi = 27.5 cm
Final Base Thickness DBSf = 15.0 cm
Subbase CBR = 30
Base CBR = 100

Solution : Subbase Thickness required = 20 cm

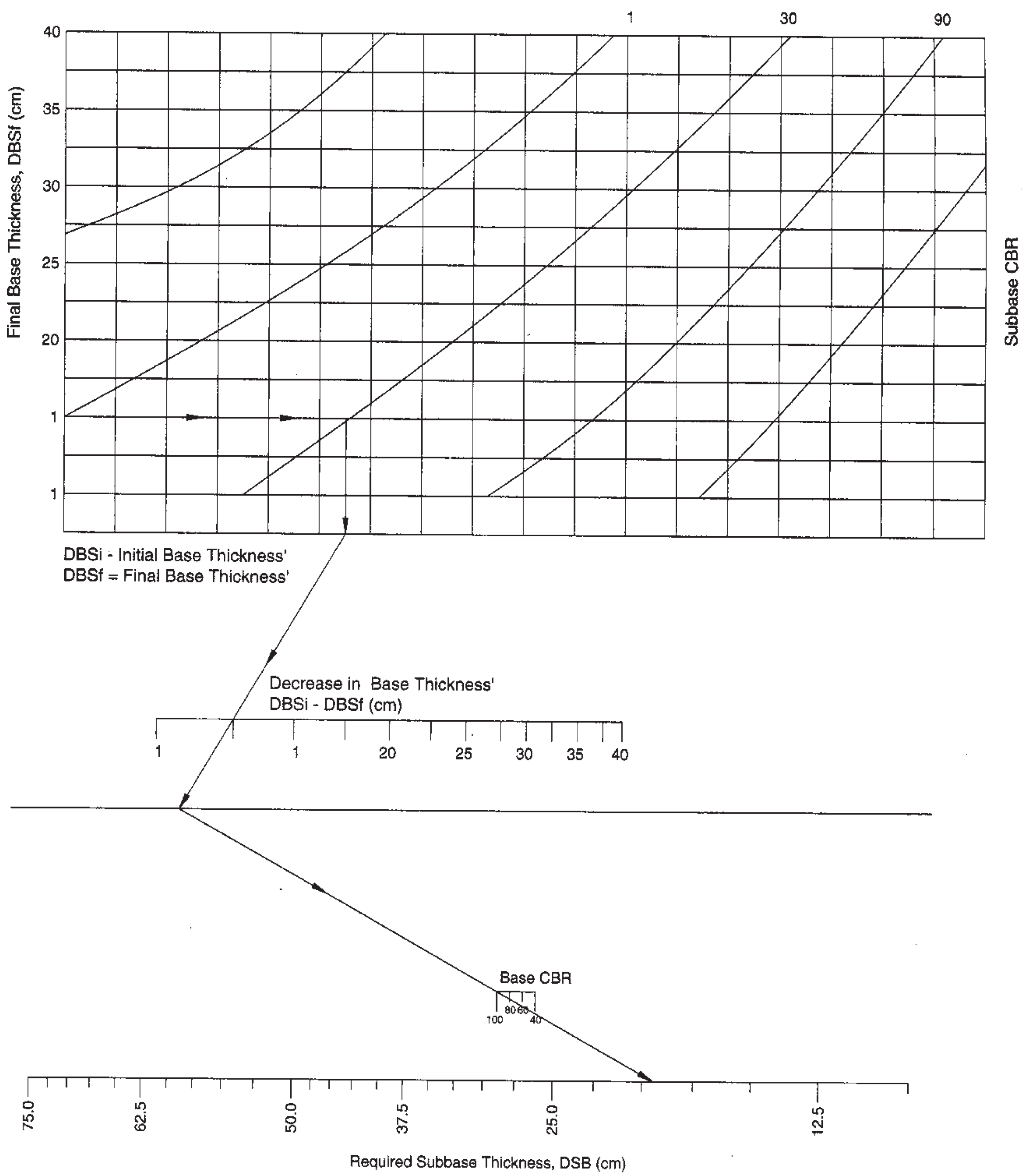


Fig. 5.5. Chart to Convert a Portion of the Gravel/Soil-Aggregate Base Layer Thickness to an Equivalent Thickness of Subbase

5.7. DESIGN OF FLEXIBLE PAVEMENT FOR TRAFFIC FLOW OVER 1,00,000 CUMULATIVE ESAL REPETITION

5.7.1 Subbase material

Granular Subbase:

Granular subbase materials conforming to Clause 401 of the MORD Specification for Rural Roads are recommended for use. These specifications suggest three gradings and specify that the materials passing 425 micron sieve should have liquid limit and plasticity index of not more than 25 and 6 respectively. The soaked CBR value should not be less than 20. In case the subbase material of the requisite soaked CBR value is not available within the economical leads, the subbase material meeting any of the prescribed gradings and other requirement with a soaked CBR value not less than 15 can be permitted with the approval of the competent authority.

5.7.2 Base course material

Gravel base materials:

For traffic upto 1,00,000 ESAL applications, gravel/soil-aggregate meeting the requirements laid down in Clause 402 of the MORD Specification for Rural Roads is found to be both suitable and economical. It may be pointed out that for the successful performance of a non bituminised gravel road surface, a gravel surfacing material meeting the requirements laid down in Clause 402 of MoRD Specification for Rural Roads must be provided. For higher traffic ranges over 1,00,00 ESAL repetitions, higher types of base materials involving the use of crushed stone material or soil-cement will be needed, and the road surface black-topped.

Macadam Base Course:

Conventionally the WBM base course has been used in India even for the low volume rural roads. However, the cost of WBM becomes uneconomical in areas where hard stones has to be carted from long distance, sometimes as much as 300km; in such cases, the possibility of using a soil-cement base course must be explored. WBM must be laid as per the specifications laid down in Clause 405 of MoRD Specification for Rural Roads, taking special care to see that the screenings and binding material

meet the required engineering properties and are used in specified quantities. Improved crushed stone base course by way of Wet Mix Macadam and Crusher Run Macadam can be used, following the specifications laid down by Clause 406 and 411 of MoRD Specification for Rural Roads respectively.

Soil-Cement Base:

Where hard stone has to be carted from long uneconomical leads, the use of soil-cement often offers an appropriate option. The soil-cement mix should be designed to attain a minimum laboratory 7-day unconfined compressive strength of 2.76 MN/m2. Special consideration must be given to pulverization of soil clods to the specified requirements and thorough mixing as laid down in Clause 404 of MoRD Specification for Rural Roads. For clayey soils, pre-treatment with lime may be needed before stabilization with cement. The thickness of base shall not be less than 150 mm.

5.8. Bituminous Surfacing

The need:

Bituminous surfacing is a relatively expensive item, and its use should be made judiciously. Even when used, the specification will not generally be higher than one/two-coat surface dressing provided as per Clause 507 of MoRD Specification for Rural Roads or 20 mm thick open-graded premix carpet as per Clause 508. A thin bituminous surfacing serves the following purposes:

- Improves the riding quality
- Seals the surface, thus preventing the entry of water which would otherwise weaken the pavement structure.
- Protects the granular base from the damaging effects of traffic

5.8.1. Warrants for bituminous surfacing:

Pneumatic-tyred fast moving vehicles like the commercial rural vehicles damage unprotected granular bases and create dust nuisance. Also, the operating costs of such vehicles are highly influenced by the smoothness of the road pavement. Bituminous surfacing will be advantageous where subgrade is poor (CBR less than 4),

the design traffic exceeds 60,000 ESAL applications, and annual rainfall generally exceeds 1000 mm. Broad guidelines for providing a bituminous surface treatment over a well-drained gravel road surface, considering the above influencing factors viz. (i) Subgrade strength, (ii) traffic volume and (iii) annual rainfall in the area are given in the table. 5.2.

Table: 5.2. Guidelines for Providing a Bituminous Surface Treatment

ANNUAL RAINFAL	TYPE OF SURFACING			
	TRAFFIC CATEGORY			
	T1 (ADT<100)	T2 (ADT=100-150)	T3 (ADT=150-200)	T4 (ADT>200)
Over 1500mm/year	Gravel	BT	BT	BT
1000-1500mm/year	Gravel	Gravel	BT	BT
Less than 1000mm/year	Gravel	Gravel	Gravel	BT

As part of the stage development strategy, it is often desirable to postpone the provision of a bituminous surface treatment for the first few years of its service life during which the pavement may undergo any undulations and the entire pavement system, including the drainage system, gets stabilized.

5.8.2 Type of bituminous surfacing

For the low volume rural roads, when a bituminous surfacing needs to be provided, two alternatives viz, Surface Dressing and 20 mm Premix Carpet are generally available. The recently revised and vastly improved IRC Specifications for Surface Dressing adopt the concept of Average Least Dimension (ALD) of stone chips and take into account, the factors of traffic, type of existing surface, climate and type of chipping. A standardised chart is used for the determination of design binder content and chipping application rate. The adoption of the revised IRC specifications make Surface Dressing both suitable and economical for low traffic volume conditions, as

borne out by its popularity in several countries abroad. However, 20 mm Premix Carpet can be used as an alternative to Surface Dressing.

5.8.3. Recommended Pavement Design

The recommended flexible pavement designs for low - volume rural roads are given in Fig.5.4. The salient features of the design catalogues are as under:

(i) There are five subgarde strength classes S1, S2, S3, S4 & S5 covering a range of CBR values from 2 to 15, for each of which, the pavement thickness and composition requirements are given under different traffic categories in terms of ESAL applications.

(ii) The traffic parameter has been categorized into 7 categories as under:

T1 : 10,000 to 30,000 ESAL applications

T2 : 30,000 to 60,000 ESAL applications

T3 : 60,000 to 1,00,000 ESAL applications

T4 : 1,00,000 to 2,00,000 ESAL applications

T5 : 2,00,000 to 3,00,000 ESAL applications

T6 : 3,00,000 to 6,00,000 ESAL applications

T7 : 6,00,000 to 10,00,000 ESAL applications

(iii) Based on long-term performance of gravel roads for low – volume rural traffic in a large number of countries, developed and developing, gravel roads perform satisfactorily upto about 60,000 ESAL applications during the design life of 10 years for any subgrade CBR above 2. If, however, the subgrade CBR is above 5, Gravel roads can perform satisfactorily upto 1,00,000 ESAL applications, during the design life of 10 years.

(iv) Black-Topped Flexible pavements need to be designed for a minimum ADT of 200 or design traffic of 1,00,000 ESAL applications, during the design life of 10 years.

(v) A minimum 150mm thick base course should be provided in the flexible pavement designs for ESAL applications from 1,00,000 to 10,00,000.

(vi) The recommended thickness in flexible pavement designs are generally multiples of 75mm or 100mm as required by practical considerations in the implementation of these designs.

(vii) All the recommended designs are amenable to further strengthening at a future date.

(viii) For flexible pavement designs with a design traffic over 10,00,000 ESAL applications, IRS:37 may be referred to. However, thick bituminous layers may not be warranted and could be substituted by granular construction.

(ix) In areas susceptible to frost action, all black-topped flexible pavements in the Design Catalogue, need to be provided with a minimum pavement thickness of 450mm(300 mm subbase + 150 mm base), even when the CBR value of the subgrade warrants a smaller thickness.

(x) The Gravel base thickness requirements for Gravel Roads as given in Design Catalogue needs to be increased in areas susceptible to frost action.

5.9. ONE-COAT AND TWO-COAT SURFACE DRESSING

Design :

Method -I

When the aggregates are just laid, the voids may be assumed to be 50 per cent, after rolling and compaction, reorientation of particles take place and voids become 30 per cent and finally when it is open to traffic the voids become about 20 per cent.

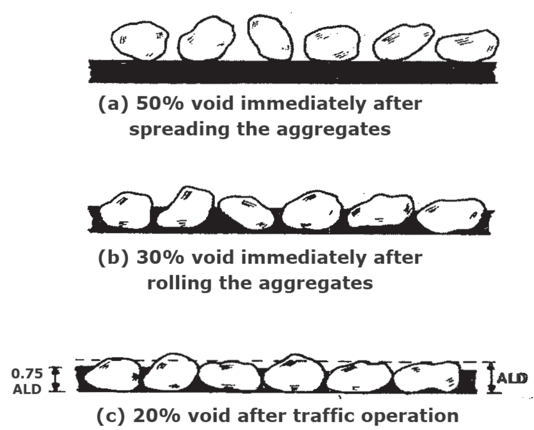


Fig.5.6. Voids at different stages of Surface Dressing construction

Thus the quanitity of aggregates required in cubic metres per m^2 of area for laying single-coat Surface Dressing is:

(80 / 50) x ALD x (1 /1000) .... (1)

Where ALD is the average least dimension of aggregates in mm.

10 per cent of the aggregates may be assumed to be lost in whip off due to traffic. Therefore, the correct estimate of required aggregate is :

(80 /50) x ALD x (110 /100) x (1/1000) ....(2)

Completed Surface Dressing where traffic is operational has voids of 20 per cent, out of which bitumen should occupy 3/4th (i.e., 75 per cent) thickness. Thus the quanitity of bitumen required in kg per m^2 of area for laying single-coat Surface Dressing is :

(75/100) x (20/100) x ALD ...(3)

However, for the case of Surface Dressing with bituminous emulsion, th binder should occupy upto the level of ALD, because, after evaporation, the level of residual bibder will be 3/4th of ALD only (as shown in Fig.5.7)

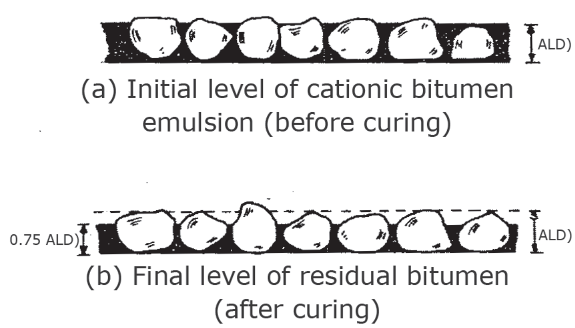


Fig.5.7. Binder thickness using bitumen emulsion

Design of two-coat Surface Dressing is to be done separately for each layer, except that the aggregate size of the second coat must be smaller than the aggregate size of first layer.

Determinaton of ALD :

If the aggregates used for Surface Dressing construction are all of same size and spherical in shape, the ALD will be equal to the median size of the aggregates, However, in reality it is not so. Empirical relationship between the median size, flakiness index and ALD has been presented in Fig. in the form of a nomograph. The sieve size through which 50 per cent of the aggregates pass is the median size of the aggregates. The flakiness index is found out separately. A line is drawn joinining the median aggregate size and the flakiness index to obtain ALD.

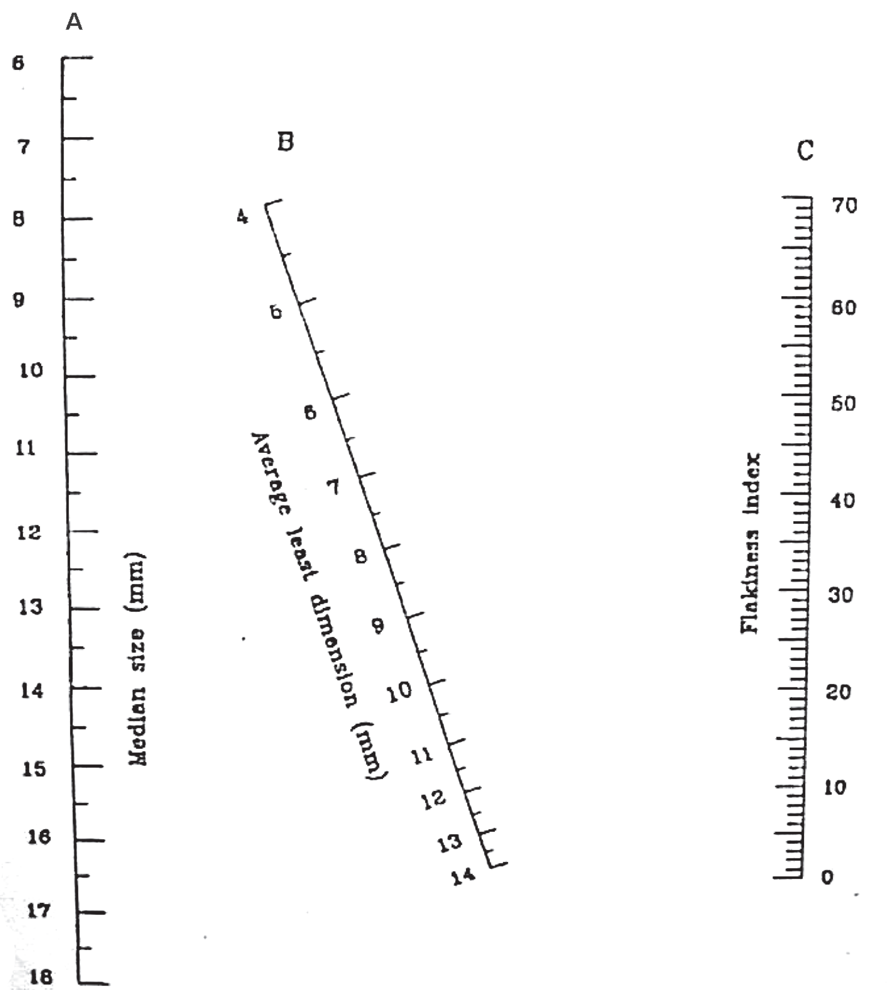
Fig.5.3. Recommended Nominal Sizes of Stone Chippings (Millimetres)

Type of Surface	Approximate Number of Commercial Vehicles with an Unladen Weight Greater Than 1.5 Tonnes Currently Carried Per Day in the Lane Under Consideration				
	2000-4000	1000-2000	200-1000	20-200	Less than 20
Very Hard	10	10	6	6	6
Hard	13	13	10	6	6
Normal	19+	13	10	10	6
Soft	•	19•	13	13	10
Very Soft	•	•	19	13	10

Note : The size of stone chippings is related to the mid-point of each lane traffic category. Light traffic conditions may make the next smaller size of stone more appropriate.

+ Very particular care should be taken when using 19 mm chippings to ensure that no loose ma terials remain surface when the road is opened to unre stricted traffic as there is a high risk of windscreen breakage.

• Unsuitable for surface dressing.



Method : Join A to C

Read average least dimension on B

Determination of Average Least Dimension

Method-II

This method is more suitable for general application. The design steps are:

1. Select nominal size of aggregates using Table
2. Select type of binder to be used.
3. Determine the ALD of the aggregates.
4. Select factors appropriate to the site of Surface Dressing from the following four Table for (i) Volume of traffic, (ii) Condition of existing surface, (iii) Climate conditions, and (iv) Type of aggregates.

(i) Volume of Traffic (IRC 110-2005, Page No. 15)

Volume of Traffic	Vehicles/lane/day (Un laden weight greater than 15 kN)	Factor
Very light	0-50	+3
Light	50-250	+1
Medium	250-500	0
Medium-heavy	500-1500	-1
Heavy	1500-3000	-3
Very heavy	3000+	-5

(ii) Condition of Existing Surface (IRC 110-2005, Page No. 15)

Condition of Existing Surface	Factor
Untreated or primed base	+6
Very lean bituminous	+4
Lean bituminous	0
Average bituminous	-1
Very rich bituminous	-3

(iii) Climatic Conditions (IRC 110-2005, Page No. 15)

Climatic Conditions	Factor
Wet and cold	+2
Tropical (wet and hot)	+1
Temperate	0
Semi-arid (hot and dry)	-1
Arid (very dry and very hot)	-2

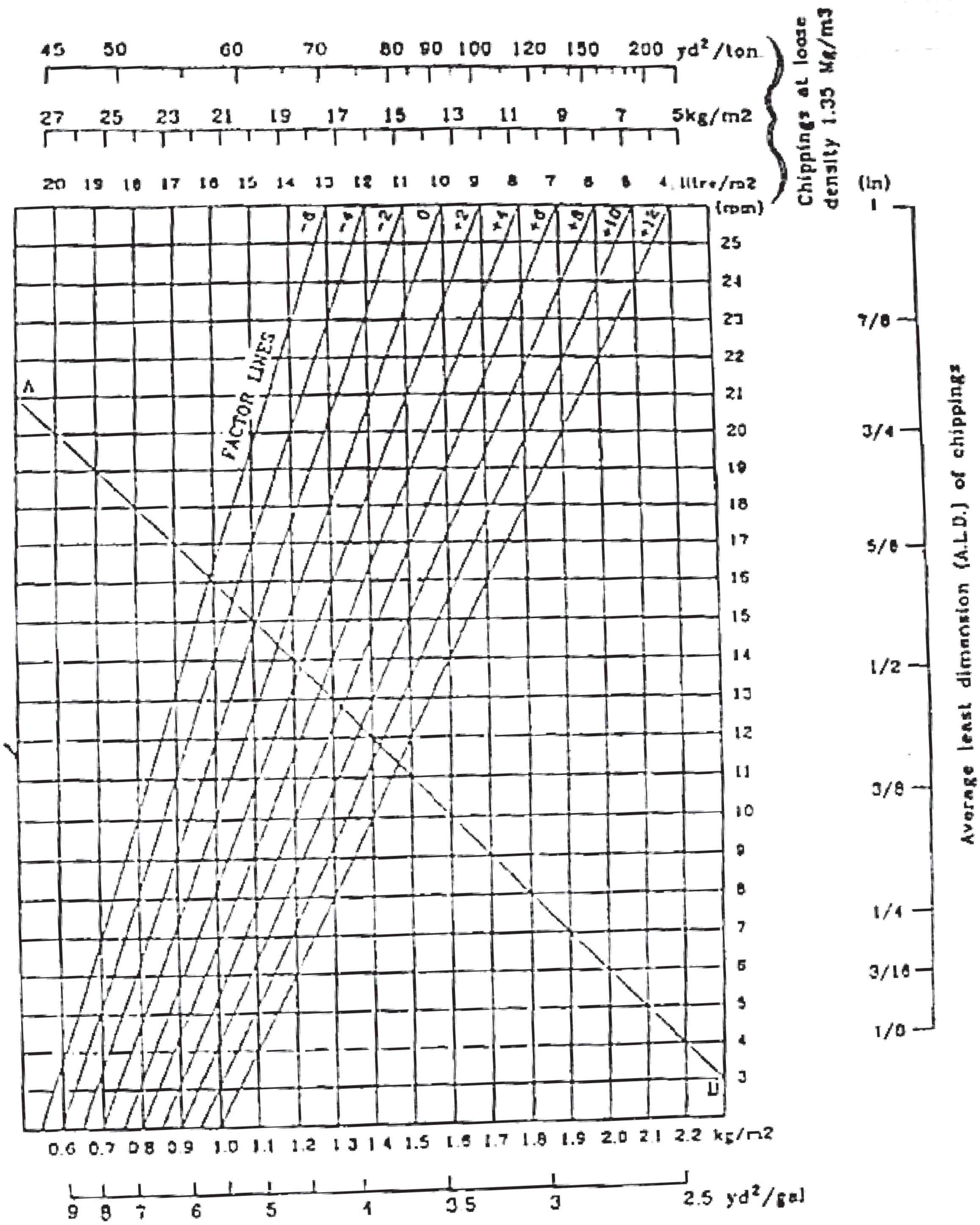
(iv) Type of Aggregates (IRC 110-2005, Page No. 15)

Type of Aggregates	Factor
Round/dusty	+2
Cubical	0
Flaky	-2
Pre-coated	-2

For example, if flaky aggregates (factor-2) are to be used at a road site carrying medium to heavy traffic (factor-1) and which has a very rich bituminous surface (factor-3) in a wet tropical climate (factor+1) the overall weighting factor is :

$$-2 -1- 3+1 = -5$$

Determine the design binder and chipping application rates by summing the four factors and entering the value in Fig. The intersection part of ALD and the factor line gives the rate of spread of binder (bottom scale).



Rate of spread of binder (cutback grades with viscosity greater than 2000 Centistokes at 60°C

Fig.5.8. Surface Dressing Design Chart

*1. For slow traffic or climbing grades steeper than 3 per cent, reduce the rate of spread of binder by 10 per cent.

*2. For fast traffic or downgrades steeper than 3 per cent increase the rate of spread of binder by 10 to 20 per cent.

The intersection part of ALD and the line AB on the top scale gives the application rete for the aggregates. The aggregates application rate includes a 10 per cent allowance for whip off.

The rate of spread of binder is adjuted to allow for the type of binder used. For penetration grade binder, decrease the rate of spread by 10 per cent.

For emulsion, multiply the rate of spread given in the char by 'Z'

Where, $$Z = \frac{90}{\text{Bitumen content of emulsion (\%)}}$$

The aggregate application rate needs to be further adjusted by observing on site whether any extra binder remains after spreading, indicating too low a rate of application, or whether there is overlapping of aggregates, indicating too high an application rate.

5.10. DRAINAGE AND SHOULDERS

5.10.1 Drainage design

It must be recognized that a scientifically worked out drainage design is a vital part of the design of pavement system as a whole. The pavement design recommended in this Manual is based on the assumption that:

(i) Proper cross – slopes are provided over the carriageway and roadside shoulders to shed off the rain water quickly.

(ii) Top of the subgrade / improved subgrade is raised sufficiently, preferably not less than 300 mm above the GL and not less than 600 mm above the highest GWT.

(iii) Adequately designed roadside ditches/drains are provided.

(iv) All cross – drainage structures are provided as per requirements.

Besides the drainage requirements as above, it is also necessary to provide drainage of pavements layers especially where the subgrade is of relatively low permeability e.g. a clay subgrade. While no separate drainage layer is considered necessary for rural roads, it is necessary that atleast half the sub-base layer thickness, subject to a minimum of 100 mm should be extended across the shoulders. In the sub – base material, the percent passing 75 micron sieve must not exceed 5%.

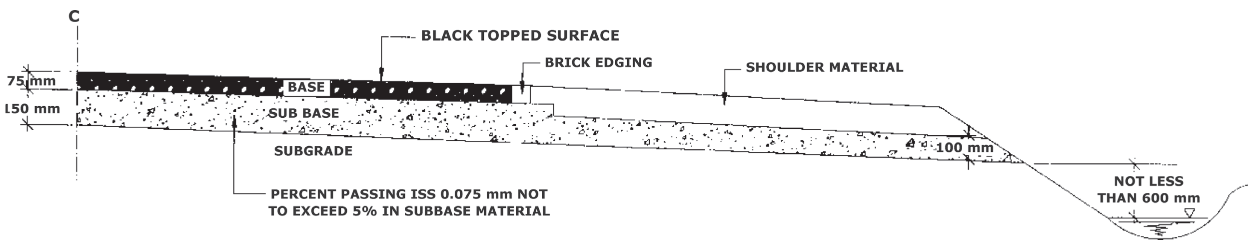


Fig. 5.9. Extended sub-base

5.10.2 Shoulders:

For the successful performance of a rural road pavement, it is necessary that adequate lateral support be provided by road side shoulders. These are all the more when the pavement materials are unbound in nature. The shoulder material should be selected using the same principles as for gravel roads or a subbase to carry construction traffic. The shoulder material should normally be of subbase quality compacted to a thickness of 100 mm. Where the anticipated traffic on the shoulders is high e.g high percentage of animal – drawn carts, graveled shoulders need to be provided over 1 m width from the edge of the carriageway as per MORD specifications for Rural Roads Clause 407. It is advisable if atleast the outer edge of shoulder is grassed with an appropriate species to prevent erosion. Where shoulders are not graveled, and the traffic volume is very low, it is advantageous to grass the whole of the shoulder.

5.11. ILLUSTRATIVE EXAMPLE

Twenty four hour traffic counts over a period of 3 days taken on a single lane rural road during the peak harvesting season, yielded the following results for the Average Daily Traffic:

Animal – drawn carts (Pneumatic Tyred)	25
Bicycles	457
Full – size trucks	9
Agricultural Tractor – Trailers and Jugads	55
Cars and Jeeps	15
Motor cycles	200
Total	**761**

(Motorized and Non – Motorized Vehicles per day)

There are two harvesting seasons in the area, each having a duration of about 2 ½ months, the harvesting season traffic remaining at its peak for 15 days. The above traffic count data was collected 2 years before opening the road to traffic.

The depth of the Ground Water Table was found to be about 10 m below Ground Level. The average annual rainfall in the region is of the order of 750 mm. The soil survey results show the subgrade soil type to be CL with a plasticity index of 13. The maximum dry density and optimum moisture content were found to be 1.68 gm/cc and 12% respectively. The CBR sample prepared at OMC, and compacted to MDD, yielded a CBR of 5. The locally available materials include river gravel and sand besides an overly plastic moorum with excessive fines. Determine the most appropriate pavement thickness and composition requirements.

5.11.1. Design Calculations

5.11.1.1. Computation of the Design Traffic Parameter

Since the lean – season traffic data is not available, it is assumed that the peak harvesting season traffic is double the traffic during the non- harvesting season. Referring to Fig. 1, n=1, t=75 days.

Average Daily Traffic during the non-harvesting season = 761/2 = 380

$$AADT = 380 + \frac{1.2 \times 380 \times 75}{365}$$

= 380+94 = 474

Before opening of the road to traffic, AADT = 474 (1.06)2 = 532, assuming an initial growth rate of 6%.

From the given traffic count data, the proportions of HCV and MCV out of the ADT of 532 work out as under:-

Heavy Commercial Vehicles (HCV) = 6

Medium Heavy Commercial Vehicles (MCV) = 38

The Animal-drawn carts being pneumatic tyred have not been considered for design purposes.

Therefore, Commercial Vehicles Per Day (CVPD) to be considered for design purposes = 6+38 = 44. Since the traffic count data does not give the proportion of unladen and laden vehicles, it is assumed that these are equal in number.

Taking the VDF values from para 3.4.4, the ESAL applications per day = 16.35

Cumulative ESAL applications over 10 years @ 6 % growth rate.

= 4811 x 16.35

= 78,660

5.11.1.2. Evaluation of Subgrade Strength

Since the GWT is too deep to influence the subgrade moisture, the design moisture may be close to the optimum moisture content. Referring to the Nomograph in Fig.2, for insitu dry density of 1.68 gm/cc, GWT depth of 10 m, PI of 13 and average annual rainfall of 75 cm, the Equilibrium Moisture Content works out to about 11 %. The optimum moisture content of 12% being higher, the CBR value of 5 may be taken for subgrade strength.

5.11.1.3. Pavement Thickness and Composition

For cumulative ESAL applications of 78,660, referring to the Traffic category in the range 60,000 to 1,00,000 and the Subgrade category of CBR 5 to 6, in Fig. 4, a 275 mm Gravel Base should be provided. The specifications for a Gravel Road as per Clause 402 of the Specifications for Rural Roads should be adopted.

REFERENCES:

1. IRC:SP:72-2007 Guidelines for the Design of Flexible Pavements for Low Volume Rural Roads, Indian Roads Congress, New Delhi

2. IRC:37-2001 Guidelines for the Design of Flexible Pavements, Indian Roads Congress,

3. IRC:110-2005 Standard Specifiations and code of Practice for design and Construction of Surface Dressing

METHODOLOGY OF ROAD CONSTRUCTION

6. METHODOLOGY OF ROAD CONSTRUCTION

6.1. SITE CLEARANCE AND SETTING OUT OF WORK

6.1.1 Site clearance

1. The road land should be cleared of all materials unsuitable for the work by cutting, removing and disposing of all materials like trees, bushes, shrubs, stumps, roots, grass, woods, top organic soil not exceeding 150 mm in thickness, rubbish etc. This should be in advance of earthwork operations.

2. All trees, stumps, etc. falling within the excavation and embankment lines should be cut to such depth below ground level that in no case they fall within 500 mm from top of the sub grade. Beyond these limits, they need to be cut down to 1m below ground level.

3. Excavation below ground level arising out of removal of trees stumps, etc, be filled in layers with suitable materials and compacted thoroughly.

4. The waste material obtained from site clearance operation must be disposed off properly as directed by Engineer in charge and should never be left at site of work.

6.1.2 Setting – out

1. Establish working bench marks at the rate of four per Km and one at or near each cross drainage on the road in question with the help of reference Bench Mark in the area.

2. Mark centerline of road and fix the pegs at a distance of 6m either side of centerline at 50 meter interval at on plain terrain & 20 meter interval on ghats & turnings. Also fix the peg at toe line of the road at the same interval.

3. Provide reference pillars on both sides of the road at 100 meter apart or as required. The location of center line may be marked with paint. These pillars can be RCC, pre-cast concrete, cut stone or any other suitable material.

4. Mark the levels of different layers i.e., embankment sub grade, GSB, G-I, G-II, & G-III etc. on reference pillars.

5. The lines and levels of formation, side slopes, drainage works, carriageway and shoulders should be carefully set out and frequently checked. Care should be taken to ensure that correct gradients and cross sections are obtained everywhere.

6. The setting out item includes setting out of cross drainage structures also. The center line, formation level, foundation level, cross pillars (Bhurji) and pegs etc. may be suitably provided.

6.2. EXCAVATION

6.2.1 Methodology :

1. The limits of excavation should be set out true to lines, curves, slopes, grades and sections as shown in the drawings. The work of excavation should be carried out in conformity with the drawings.
2. Undertake stripping of top soil before excavation if so required under the contract and stack it suitably for reuse.
3. Keep the excavation dry.
4. After excavation, the sides of excavated area should be trimmed and the area contoured to minimize erosion and ponding, allowing natural drainage to take place.
5. In case in-situ soil is to be used to sub grade, loosen the soil and compact to a thickness of 300 mm with a suitable roller to 100 percent standard proctor compaction density layers of 150 mm thick.

6.3. EMBANKMENT / SURGRADE

6.3.1 Methodology:

1. Where necessary, the original ground should be levelled and rolled to facilitate placement of first layer of embankment. The soil for processing should be brought to proper moisture content, so that the needed degree of compaction can be achieved with least effort. Needed amount of water should be uniformly spreaded or sprinkled in the entire soil mass. Depending upon the weather conditions and time gap between sprinkling of water and commencement of rolling, an allowance of 3 to 4 percent for evaporation should be made in the quantity of water to be

added during summer when temperature is grater than 35^0 C. In winter their allowance may be reduced to 1 percent.

2. The soil should be spread in layers to achieve not exceeding 150 mm compacted thickness. Each layer should be thoroughly compacted to the specified requirements and finished parallel to the final cross section of the embankment (layer thickness can be increased to 22.50 cm. if heavy vibratory rollers are used.)

3. The loose thickness may be decided judiciously by the engineer-in-charge by making test strips of various thickness and arriving at the proper loose thickness of the soil being used.

4. Embankment is compacted to achieve a field density not less than 97 percent of standard proctor compaction density (The compaction is restricted to 90% of standard proctor density in case of expensive soil). It is necessary to further ensure that the top 300 mm of embankment i.e. sub grade is constructed by soil having CBR value not less than 7% in case were local soil CBR is less than 4 or as provided in DPR. The sub grade is compacted to 100 percent standard proctor compaction. The Engineer in-charge should also verify other soil property also and in case of variation from DPR, approval of variations may be obtained from competent authority.

5. The profile of embankment and sub grade should be made with the help of motor grader and it may be checked with working drawings.

6.3.2. Stabilization of local Soil :

A variety of techniques are available for stabilizing local soils for improving their engineering properties, but not all the techniques are applicable to all types of soils. A brief description of the stabilization mechanism and applicability of the individual techniques are given in Table. 6.1. This may be referred to for choosing the most appropriate technique for stabilizing the soil at sit. The mix proportions are generally worked out in the laboratory based on soaked CBR.

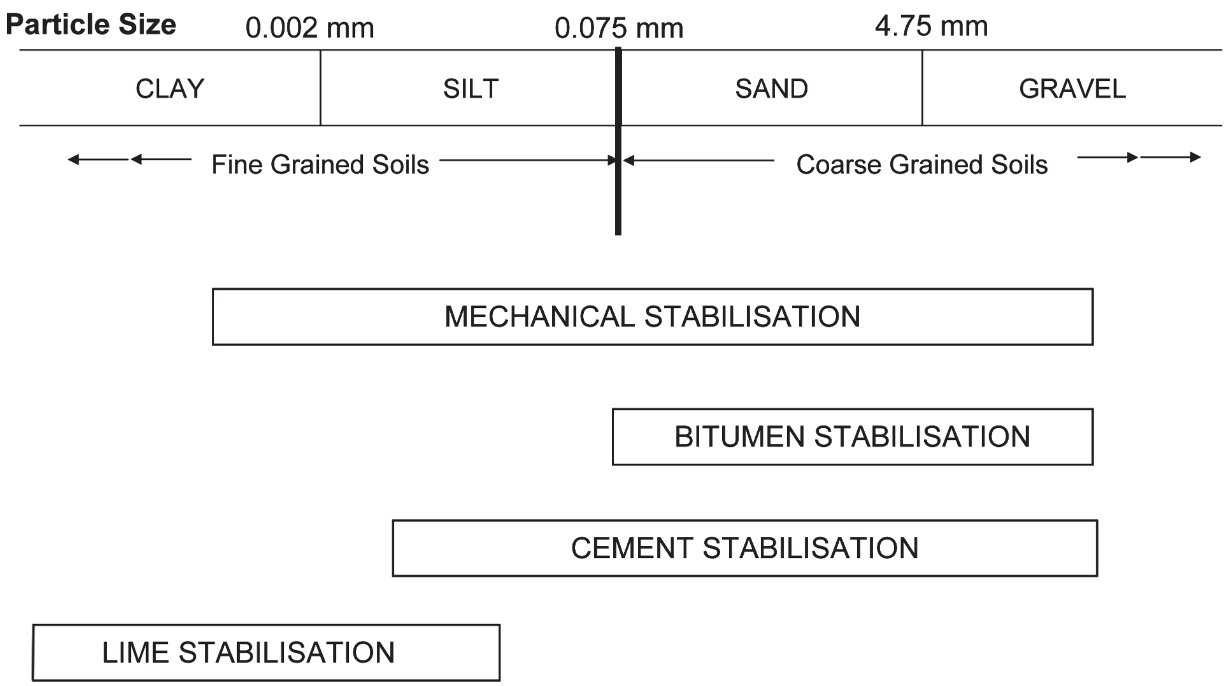
Table 6.1 Mechanism and Requirements of Soil Stabilisation Techniques (IRC SP : 72 - 2007, Page No. 18)

Sl. No.	Technique	Mechanism	Application
1.	Mechanical stabilisation	Blending missing fractions (e.g., clay with sand and sand with clay) so as to produce a mass of maximum possible density with plasticity within limits. A smooth grading similar to that given by Fuller's grading rule** is adopted to work out the proportion of the missing fractions to be blended.	Sands, moorum/ gravel having missing fractions and clayey soils can be stabilised by this technique.
2.	Lime stabilisation	Lime in hydrated form reacts with the clay minerals in the soil to cause (i) immediate reduction in plasticity and increase in CBR because of cationic exchange, flocculation and agglomeration, which may be reversible under certain conditions, and (ii) long term chemical reaction with the clay minerals to produce cementitious products which bind the soil for increased strength and stability.	Medium and heavy clays having a PI of at least 10 and containing at least 15% of materials finer than 425 micron are suitable. However, some soils though containing clay fractions may not produce the long-term chemical reaction because of the presence of organic matter (> 2%), or soluble sulphate/carbonate (> 0.2%) etc. For lime stabilisation to be successful, it will be desirable to test the soil for lime reactivity. A soil whose 7-day unconfined compression strength increases by at least 3 kg/ cm2 with lime treatment can be considered lime reactive.
3.	Cement stabilisation	The hydrated products of cement binds the soil particles, the strength developed depending on the concentration of cement and the intimacy with which the soil particles are mixed with cement. A high cement content of the order of 7-10% can produce a hard mass having a 7-day	Generally, granular soils free of high concentration of organic matter (2% or deleterious salts (sulphate and carbonate 0.2%) are suitable. A useful rule for soil selection is that the plasticity modulus (product of PI and fraction passing 425 micron sieve) should be less than

		compressive strength of 20 kg/cm2 or more, and this usually goes by the term soil-cement. However, a smaller proportion of 2-3% cement can improve the CBR value to more than 25, and the material going by the term "cement-modified soil" can be advantageously used as sub-base/base for rural roads.	250 and that the uniformity coefficient should be greater than 5.
4.	Lime-flyash stabilisation	Lime chemically reacts with the silica and aluminium in flyash to form cementitious compounds, which bind the soil.	Soils of medium plasticity (PI 5-20) and clayey soils not reactive to lime can be stabilised with lime and flyash.
5.	Bitumen stabilisation	Bitumen binds the soil particles.	Clean graded sands can be stabilised by this technique.
6.	Two-stage stabilisation	This generally applies to heavy clays. The clay is treated with lime in the first stage to reduce plasticity and to facilitate pulverisation. In the second stage, the resulting soil is stabilised with cement, bitumen, lime or lime-flyash.	Heavy clays.

** Fuller's grading rule is given by :

$$\text{Per cent passing sieve} = 100 \times \left[\frac{\text{aperture size of sieve}}{\text{Size of the largest particle}}\right]^{\frac{1}{2}}$$



6.3.3. Mechanically Stabilized Soil Sub-base

(1) Preparation of subgrade : Prior to the laying of the sub-base, the subgrade already finished to the specified profiles should be prepared by removing all vegetation and other extraneous matter, lightly sprinkled with water if necessary and rolled with two passes of 80-100 kN static weight roller.

(2) Sequence of operations : The sequence of construction operations should be such that the construction of mechanically stabilized soil subbase layer should match the construction of the adjoining layer in the shoulders.

(3) Mixing of local materials : Mixing should be done mechanically by the mix-in-place method. The equipment used for mix-in-place construction should be a tractor-towed Rotavator (Fig. 13) or similar equipment capable of mixing the materials to the desired degree. In case of stabilization of clay with sand, depending on the natural moisture content, the borrow areas may be pre-wetted for facilitating excavation and addition of moisture. The clay should be excavated and clods broken by 4-6 passes of tractor-towed disc harrows (Fig. 14). Manual mixing should be permitted only where the width of laying is not adequate for mechanical operations, as in small-sized jobs.

(4) Moisture control : The moisture content of loose material should be checked and suitably adjusted by sprinkling water from a trailer mounted water tank suitable for applying water uniformly and at controlled quantities to variable

widths of surface or other means approved by the Engineer so that, at the time of compaction it is within ±2% of the OMC as per IS : 2720 (Part 7). While adding water, due allowance shall be made for evaporation losses. After waterhas been added, the material should be processed by tractor-towed disc harrows/ rotavators until the layer is uniformly wet.

(5) **Compaction :** If the thickness of the compacted layer does not exceed 100mm, a smoothwheeled roller of 80-100 kN static weight may be used. For a compacted single layer upto 225mm, the compaction should be done with the help of a vibratory roller of 80 to 100kN static weight. Rolling should commence at the lower edge and proceed towards the upper edge longitudinally for portions having uni-directional cross fall and superelevation and should commence at the edges and progress towards the center for portions having cross-fall on both sides. Each pass of the roller should uniformly overlap not less than one-third of the track made in the preceding pass. During rolling, the grade and cross-fall should be checked with templates. Rolling should be continued till the density achieved is atleast 100% of the max. dry density as per IS: 2720 (Part 7).

(6) **Aggregate Plugs :** When the mechanically stabilized soil sub-base is extended over the full formation, the exposed edges should be protected with suitable aggregate plugs, 200 to 300mm wide.

6.3.4. Soil-Aggregate Subbase/Base/Surface Course

(1) **Preparation of Surface :** The surface of the subgrade/sub-base/base, as the case may be, to receive the Gravel/Soil-Aggregate course should be prepared to the specified lines and cross-fall and made free of dust and extraneous material. Any ruts or soft yielding places should be corrected and rolled until firm surface is obtained, if necessary by sprinkling water. Any irregularities, where predominant should be made good by appropriate type of leveling course.

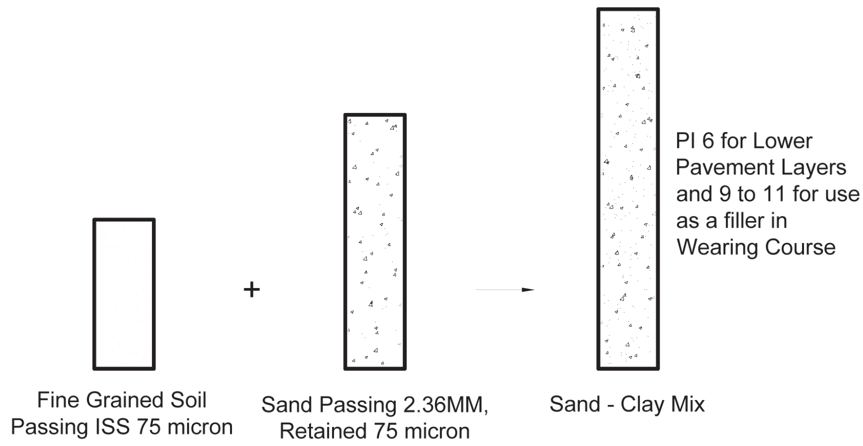
(2) **Combining Materials :** For purposes of combining different materials in the required proportions to obtain the specified grading, mix-in-place method should be used using equipment like tractortowed Rotavator. Manual mixing may be resorted to only where the width of laying is not adequate for mechanical operations, as in small-sized jobs.

(3) **Spreading :** The Gravel/Soil-Aggregate material of specified grading should be spread on the prepared surface with the help of a grader (Fig. 15) of adequate capacity, for maintaining the required slope and grade during the operation.

(4) **Moisture Control :** The moisture content of the loose material should be checked and suitably adjusted by sprinkling additional water from a truck/trailer mounted water bowser, suitable for applying water uniformly at controlled quantities to variable widths of surface, so that it is within 2% of the OMC as per IS: 2720 (Part 7). While adding water, due allowance should be made for evaporation losses.

(5) **Uniform Mixing with Water :** After water has been added, the material should be processed by mechanical means like tractor-towed disc harrows, rotavators until the layer is uniformly wet.

(6) **Rolling :** With the use of 80-100 kN static weight roller, the thickness of the compacted layer should not exceed 100mm. For a compacted single layer upto 225mm, the compaction should be done with the help of a vibratory roller of 80 to 100kN static weight. Rolling should commence at the lower edge and proceed towards the upper edge longitudinally for portions having unidirectional cross fall and superelevation and should commerce at the edges and progress towards the centre for portions having cross fall on both sides. Each pass of the roller should uniformly overlap not less than one-third of the track made in the preceding pass. During rolling, the grade and cross fall should be checked and any high spots or depressions, which become apparent, should be corrected by removing or adding fresh material. The speed of the roller should not exceed 5 km per hour. Rolling should be continued till the density achieved is atleast 100% of the max. dry density for the material as per IS:2720 Part 7. The surface of any layer on completion of compaction should be well-closed, free from compaction planes, ridges, cracks or loose material. All loose, segregated or otherwise defective areas should be made good to the full thickness of layer and recompacted.

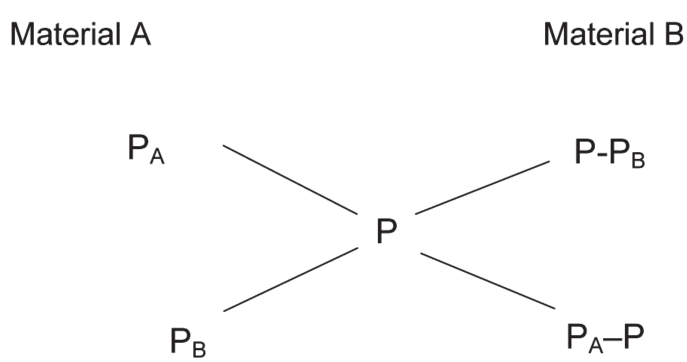


- Clayey soils needed for sands and soil gravels 10-35%
- Sand needed for silty (alluvial soil types) soils 15-30%
- Sand needed for clayey/BC soil 40-60%

Sand-Clay Mixes

Proportioning

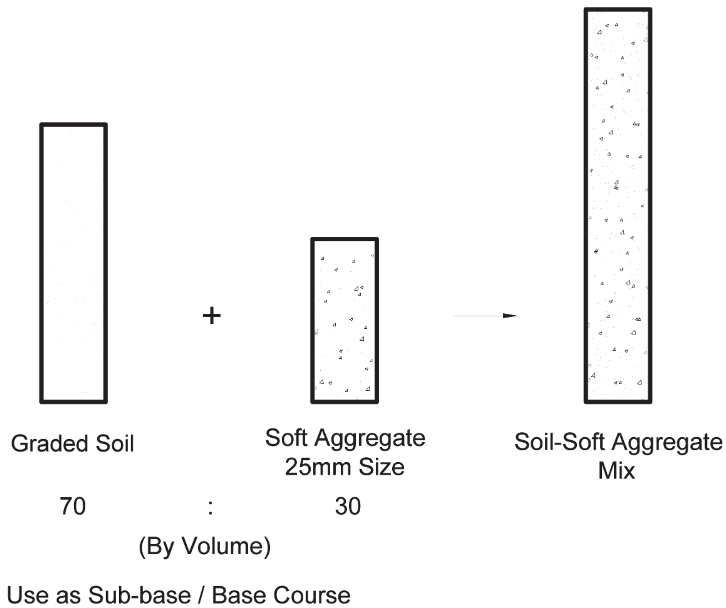
Two soils A&B with plasticity indices PA&PB can be proportioned to produce a material having the required plasticity index P. Record the values of PA and PB at the top ends of a cross, P at the crossing point. Determine the numerical differences PA – P and P – PB. The ratio in which the two soils should be mixed are Indicated at the lower ends.



Mat . A : Mat. B : : $P\text{-}P_B$: $P_A\text{-}P$

(b) Soil-Low Grade Aggregates

By blending soil with low grade aggregates like kankar, laterite, moorum, brick aggregate etc. The object is to develop a material which could be used as base course for low volume rural roads (and subbase course for highly trafficked roads).



Soil-Soft Aggregate Mixes

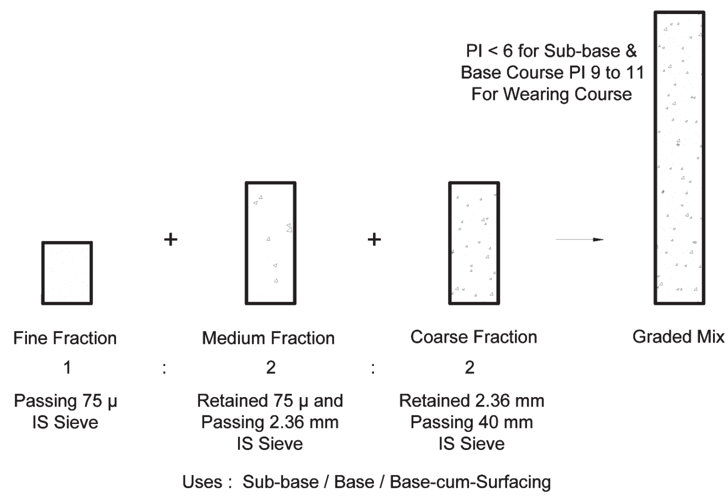
The process involves two steps :

Step 1 : Mixing of two locally available soils to obtain the required plasticity index in case the local soils do not meet the requirements, as such.

Step 2 : Mixing of the material obtained in step 1 with soft aggregates.

(c) Soil Gravel Mixes

By blending the locally available soils, gravels/ moorums with the missing fraction (s) to achieve a well graded material conforming to the specified gradation and plasticity index requirements.



6.3.5. Lime Treated Soil Subbase

(1) Excavation and Pulverization : The borrow area soil after excavation should be pulverized to the required degree (i.e, 100% passing 26.5mm sieve and not less than 80% passing 5.6mm sieve) using agricultural implements like tractor towed disc harrows and rotavators. The pulverized soil should be stacked either on the prepared subgrade or at nearby locations.

(2) Addition of water : The stacked soil should be divided into compartments, about 1.5m x 1.5m and the required quantity of water added.

(3) Addition of Lime : Lime may be mixed with the prepared material either in slurry form or dry lime. The dry lime should be prevented from blowing by sprinkling water on the lime. The tops of windrowed material may be flattened or slightly trenched to receive the lime. The distance to which lime may be spread upon the prepared material ahead of the mixing operation should be determined at the site. No traffic other than the mixing equipment should be allowed to pass over the spread lime until after completion of mixing.

(4) Mix-in-place method of construction : The equipment used should be either of single pass or multiple pass type. Appropriate tractor-towed equipment are suitable for performing various operations in the construction process like pulverization of soil clods by tractor-towed disc harrows and mixing of soil with lime by tractor-towed Rotavator. Mixing or remixing operations, regardless of equipment used, should continue until the material is free of any white streaks or pockets of lime and the mixture is uniform. Non-uniformity of color reaction, when the treated material is tested with the standard phenolphthalein alcohol indicator, shall be considered evidence of inadequate mixing.

(5) Construction with manual means : Where manual mixing is permitted, the soil from borrow areas should first be freed of all vegetation and other deleterious matter and placed on the prepared subgrade. The soil should then be pulverized by means of crow-bars, pick-axes, or other approved means. Water in requisite quantities may be sprinkled on the soil for aiding pulverization. On the pulverized soil, lime in requisite quantity should be spread uniformly and mixed thoroughly by working with spades or other similar implements till the whole mass is uniform. After adjusting the moisture content to be within limits, the mixed material should be leveled upto the required thickness so that it is ready to be rolled.

(6) Moisture content prior to compaction : The moisture content checked prior to compaction should be within 2 percent of the optimum moisture content corresponding to IS:2720 (Part 7).

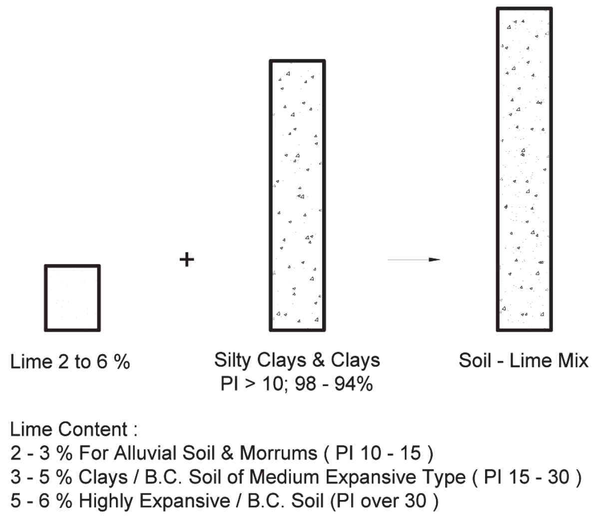
(7) Compaction : Immediately after spreading, grading and leveling of the mixed material, compaction should be carried out with 80-100 kN static weight roller. Rolling should begin at the edges and progress towards the centre on straight portions. On super elevated curves, the rolling should proceed from the inner to the outer edge. Compaction should continue until the density achieved is atleast 100 percent of the maximum dry density of material as per IS:2720 (Part 7). Ideally, not more than 60 minutes should elapse between the start of moist mixing and start of compaction process. Care should be taken to see that compaction is completed within 3 hours of mixing. During rolling, it should be ensured that the roller does not bear directly on hardened or partially hardened treated material previously laid other than what may be necessary for achieving the specified compaction at the joint. The final surface should be wellclosed, free from movement under compaction planes, ridges, cracks or loose material. All loose or segregated or otherwise defective areas, should be made good to full thickness of the layer and recompacted.

(8) Curing : Curing of the compacted layer should be carried out for a minimum period of 7 days by spreading moist straw/wet gunny bags or sand and sprinkling water periodically. Curing by ponding of water should not be permitted to avoid leaching of lime. After the curing period is over, subsequent pavement layers should be laid as early as possible to prevent the surface from drying out. No traffic should be allowed to ply during the curing period.

(i) Lime Stabilisation

When the local soil/ soil-gravel/ moorum cannot be economically and effectively stabilized by mechanical methods, the chemical stabilisation of these materials is

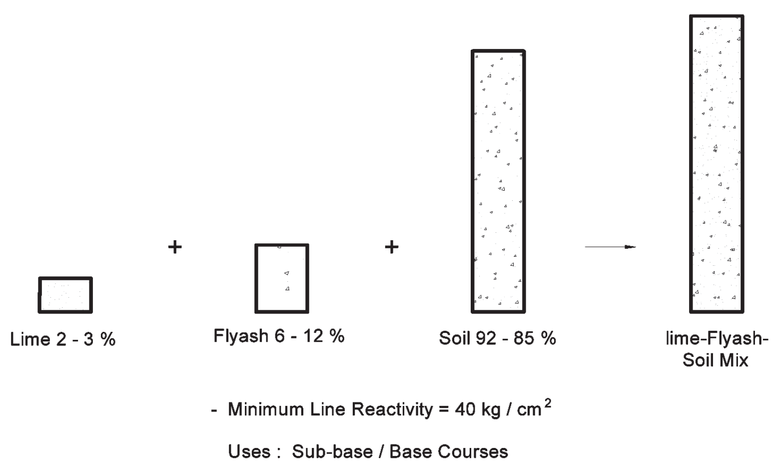
resorted to. Lime stabilisation is normally adopted for silty clays and clayey soils. The development of strength in soil-lime mixes depends on the type of clay and its quantity in soils. Thus lime stabilisation is recommended for soils having PI > 10. It is desirable that the calcium hydroxide content in lime for stabilisation should be more than 70%. In case of inferior lime the quantity of lime for stabilisation has to be increased proportionally.



Soil-Lime Mixes

(ii) Lime-Flyash-Soil Stabilisation

This method is suitable for areas where good quality flyash and lime are locally available and the local soils respond to this technique. Normally, soils having medium plasticity index (5 to 20) and clays that do not respond to lime can be improved by this technique

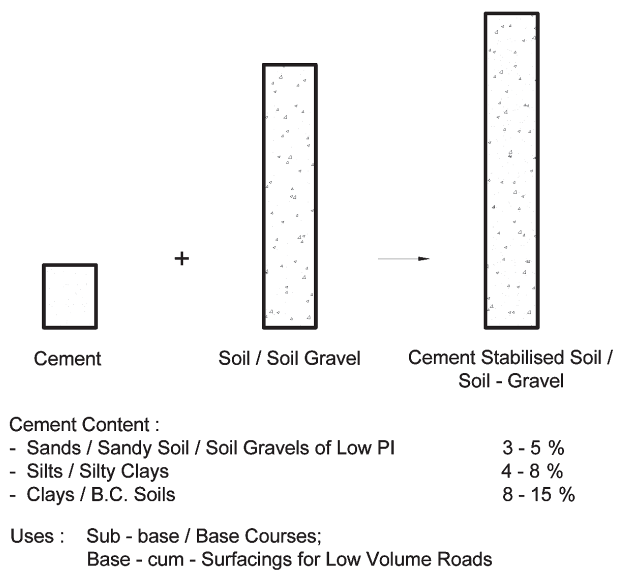


Soil-Lime Flyash Mixes

6.3.6. Cement Stabilized Soil Subbase/Base

The same steps should be followed as for the construction of lime-treated soil subbase given in section 3.5, except that care should be taken to see that the compaction of cement stabilized materials is completed within two hours of its mixing.

This method is recommended for soils which do not respond to lime and comparatively higher and faster development of strength and durability characteristics are needed, specially for waterlogged and high rainfall areas. Granular soils/ sandy soils free from harmful salts and organic matter are suitable. Proportioning of cement-soil mixes is illustrated below.



Soil-Cement Mixes

6.4. GRANULAR SUB – BASE

6.4.1 Methodology:

a) Obtain materials from approved sources. The material should be natural sand, moorum, gravel, crushed stone, crushed slag, granulated slag, crushed concrete, brick metal and kankar etc.

b) Immediately prior to the laying of sub-base, sub grade shall be prepared with the help of a motor grader of adequate capacity. The granular material for sub-base shall preferably be natural. Mixing of ingredients to make granular sub-base may be undertaken as per gradation requirment under strict quality control.

Manual methods shall be permitted only where the width of laying is not adequate for mechanical operations or in small sized jobs. Moisture content of loose material shall be checked in accordance with IS:2720(Part 2). After water has been added+1 percent to -2 percent of OMC as per IS : 2720 (Part 8) – 1993), the material shall be processed by mechanical or other approved means like disc harrows, rotavators, until the layer is uniformly wet. Immediately thereafter, rolling shall start.

c) The sub-base material should be spread in layers not exceeding 100 mm compacted thickness. (If suitable vibratory rollers are available, the thickness of layer can be up to a maximum of 225 mm). Each layer should be thoroughly compacted with rolling commencing from edge to centre for portions having cross fall on both sides (for portions having unidirectional super elevation, rolling should commence at the lower edge and proceeding towards the upper upper edge). Each pass should overlap by one-third of the track made in the preceding pass. Speed of roller should be less than 5 kmph. The rolling should continue until density achieved is at least 100 percent of the maximum dry density determined as per IS : 2720 (Pt.7). The surface of any layer of material on completion of compaction shall be well closed, free from movement under compaction equipment and from compaction planes, ridges, cracks or loose material.

Note: *Where the sub grade is clayey and impermeable, with CBR less than 4 and annual rainfall more than 1000 mm, it is desirable to provide a drainage layer of dust free coarse to medium sand of 100 mm thickness over the subgrade in full formation width. Permeability value of sand ranges from* 10^{2} *to* 10^{4} *cm per second Permeability can be determined with the help of parameters immediately following the spreading of sand, and its watering followed by rolling done at optimum moisture content*

6.5. WATER BOUND MACADAM BASE

6.5.1 Methodology:

1. WBM base course shall be constructed in conformity with line, grades and cross sections shown in the drawings of tender document. The existing surface of sub

grade or sub base to receive WBM course shall be prepared to the specified grade and camber and cleared of all dust. Any ruts or soft yielding places that have appeared due to improper drainage of surface under traffic or season shall be corrected and rolled. Any sub-base/base/surface irregularities, where predominant, shall be made good by providing appropriate type of profile corrective course (levelling course).

2. Spread the coarse aggregate uniformly on the prepared base to proper profile by using templates placed for specified compacted thickness. The thickness of one compacted layer should be 100 mm for grading 1 and 75 mm for grading II & III. (In no case metal shall be dumped in heaps directly on a partly compacted base).

   The coarse aggregate as spread shall be of uniform gradation with no pockets of fine material. The aggregate shall be hand packed properly to ensure inter locking. Immediately after spreading aggregates rolling is started with 3 wheeled power roller of 8 – 10 tonne capacity of tandom or vibratory roller of 80 to 100 KN static weight. On superelevated portions the rolling shall be proceed from inner to the outer edge. On normal straight portions rolling shall begin from the edge gradually progressing towards centre. First the edge shall be compacted with roller running forward and backward. The roller shall then move inward parallel to centre line of the road, in successive passes uniformly overlapping preceding tracks by at least one half of the width. Rolling shall be discontinued when the aggregates are partially compacted with sufficient void space in them to permit application of screenings.

3. After coarse aggregates have been rolled, the screening shall be applied gradually over the surface to fill the interstices. These shall not be damp or wet at the time of application. Dry rolling shall be done while the screenings are being spread so that vibration of the roller causes them to settle into voids of the aggregates. The screening shall not be dumped in piles but applied uniformly in successive their layers either by spreading motion of hand shovels or mechanical spreaders. The screenings shall be applied at slow rate in three or more application as necessary. Rolling and brooming shall accompany this. After application of screenings, the surface shall be sprinkled with water, swept and rolled. The sprinkling, sweeping and rolling operations shall be continued and additional

screenings should be applied where necessary until the coarse aggregates are well bounded and firmly set. The coarse aggregates shall not normally be spread more than 3 days in advance of the subsequent construction operations.

(Note : In case of lime treated soil sub-base, construction of water bound macadam on top of it can cause excessive water to flow down to the lime treated sub-base before it has picked up enough strength (is still "green") and thus cause damage to the sub-base layer. The laying of water bound macadam layer in such cases shall be done after the sub-base attains adequate strength, as directed by the Engineer.

4. After application of screenings, binding material (PI 4-6) shall be applied at uniform rate in two or more successive thin layers at a slow and uniform rate. After each application the surface shall be sprinkled with water and resulting slurry swept-in with brooms so as to fill voids properly. After final application the surface should be allowed to cure over night. Next morning hungry spots shall be filled with screenings or binding material as directed, lightly sprinkled with water if necessary and rolled. No traffic shall be allowed on the road until the macadam has set. The compacted water bound macadam course should be allowed to completely dry and set before the next pavement course is laid over it.

6.6. Wet Mix Macadam Base :

1. WMM consists of laying and compacting clean, crushed, graded aggregate and granular material, premixed with water, to a dense mass on a prepared sub-grade/sub-base or a WBM layer. The thickness of a single compacted layer of WMM shall not be less than 75 mm. When vibratory roller or other type of approved compacting equipment is being used, the compacted thickness of single layer may be increased up to 200 mm.

2. WMM shall be prepared in an approved mixing plant of suitable capacity having provision for controlled addition of water and mixing like pug mill or pan type mixer. The optimum moisture content of the mix shall be determined as per modified proctor test after replacing material retained on 19 mm sieve with material of 4.75 to 19 mm size. OMC may also be determined in the field during proof rolling.

3. The mix shall be spread by a paver finisher or a motor grader or a combination of both. Use of paver finisher should be preferred to motor grader. Compaction can be carried out using 8-10 ton vibratory roller. If the thickness of single compacted layer is less than 100 mm, static rollers can also be used.

6.7. Crusher Run Macadam

The aggregate of specified gradation shall be uniformly deposited on the approved sub grade by the means of the falling vehicle with or without spreading devices. After the base course material has been deposited which shall be thoroughly mixed to full depth of layer by alternately blading the entire layer to the centre and back to the edges of the road which shall then be spread and finished to the required cross section by means of a motor grader. Water shall be applied during all blading and processing operations to prevent segregation of the fine and coarse particles and during construction to assist in compaction. Crusher Run Macadam (CRM) broadly makes use of aggregates crushed in a crushing plant as such so that the crushed aggregate mass represents particles of different sizes and hence a dense mix is obtained when such a layer is compacted.

6.8. INTERFACE TREATMENTS

Profile Correction (Section 501.8, MoRTH)

Before laying any pavement layer over an existing pavement it is essential to check and correct the following deficiencies:

i. Proper patching of pot holes, ruts due to cutting, etc

ii. Correction of cross slope, viz., camber on straight stretches and superelevation at horizontal curves

iii. Depression or longitudinal undulations on pavement surface

The materials to be used for profile correction should be in conformity with the material in the receiving pavement layer. The corrections should be made as per the appropriate guidelines, after cutting and removing the base materials on the existing surface. The receiving layer is to be coated by prime coat and/or tack coat before placing any bituminous mix for patching/profile correction. The patches and profile correction layers should be adequately compacted using appropriate compaction

machinery. Small vibratory rollers are ideally suited. For small patches, mechanical tamper or plate vibrator may be used.

Where specified, a Profile Corrective Course shall be provided prior to laying of bitumious surfacing.

The Profile corrective course is essentially a levelling course laid to varying thickness as shown on the drawings for correcting the existing pavement profile which has either lost its shape or has to be given a new shape to meet the requirement of specified lines, grades and cross section. It shall be differentiated from the strengthening course or other type of structural pavement course needed as a remedial measure against inherent deficient and/or distressed pavement. It is meant to remove the irregualrity in the existing road profile only.

Note: Where the maximum thickness of the profile corrective course is less than 40mm, the profile corrective course shall be laid as an integral part of the overlaying layer. In other cases, the profile corrective course shall be constructed as a separate layer. When it is laid as a separate layer, type of material for the use as the profile corrective course may differ.

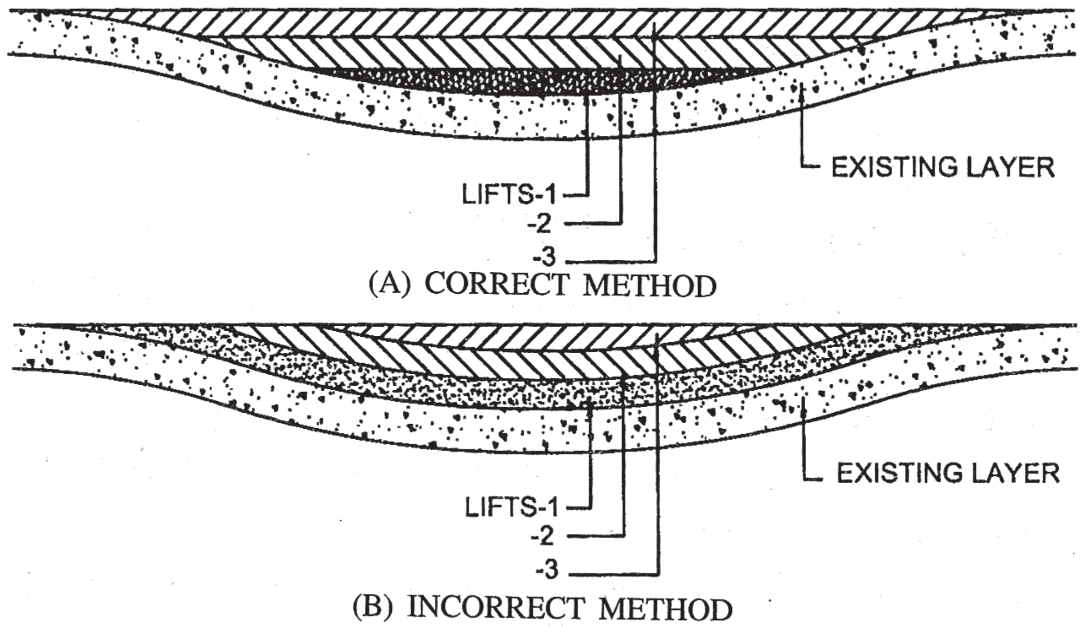
Over an existing bituminous surface, the Profile Corrective Course shall be of premixed bitumious material. Where the existing surface is granular in nature, or where the old bituminous layer has been scarified and the required thickness of Profile Corrective Course is over 40mm, the Profile Corrective Course shall be with WBM (G3) material. If, however, the required thickness of the Profile Corrective course is less than 40mm, the Profile Corrective Course shall be premixed bituminous material.

Laying the profile corrective course

On granular base : After preparing the granular surface, the profile corrective course with material shall be laid and compacted to the requirment of the particular Specificaton. Where a bituminous profile corrective course is to be laid over a primed granular surface, a tack coat shall be applied prior to laying the profile corrective course.

On bituminous surface : The existing bituminous surface shall be prepared after applying a tack coat. The bituminous profile corrective course shall be laid and compacted to the requirement of the particular Specification.

Correction of short sags or depressions : In specific situation of short sags or depressions in the pavement, it may become necessary to provide corrective course in the from of flat wedges. Normally, layers in maximum thickness of each layer at any point shall not be more than 100mm. In placing multiple lifts, the lift of shortest length (at the lowest portion of the sag/depression) shall be provided first, with successive lifts extending over and fully covering underneath layer, precluding development of a series of joints on the surfaces, as illustrated in Fig.6.1



Note: Profile corrective course material to be in accordance with the lift thickness.

Fig. 6.1. Methods for providing correcitive course for short sages and depressions

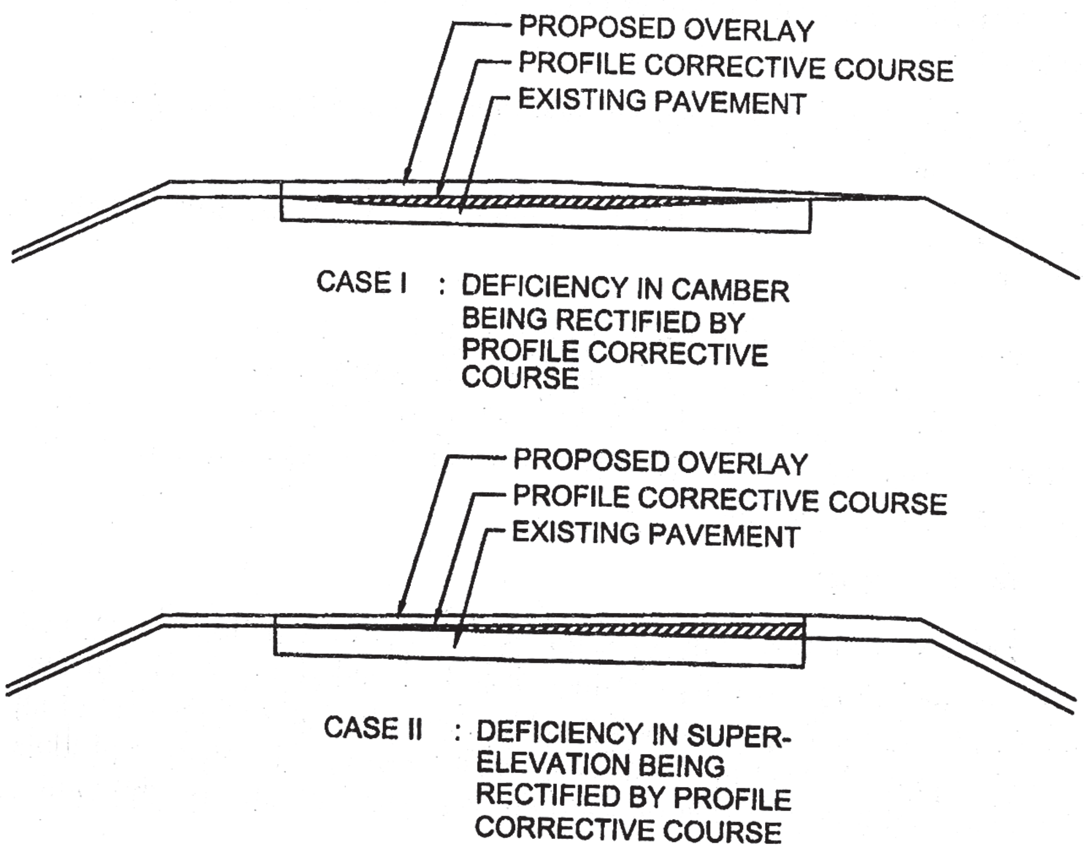


Fig. 6.2. Correction of camber or superelevation

6.9. Filling potholes and patch repairs

(a) Preparation of the area pothole and patch repair

Pothole and patch repair area shall be inspected and all loose material removed. The area shall be cut / trimmed with hand tools suitable for all purpose, such that the defective material responsible for the failure is all removed and such that the excavation is of a rectangular shape. The edges of the excavation shall be cut vertically. The area shall be thoroughly cleaned with brush. compressed air or any appropriate method approved by the Engineer to remove all dust and loose particles. Layers below the level of the bituminous construction shall be replaced using material of equivalent specification to the original construction, which shall particularly include the standards of compaction. The area of bituminous construction shall be tacked or primed, preferably with an emulsion depending upon whether the lower area is bituminous or granular in nature. The sides, however, are to the painted with tack coat material using a hand brush/ sprayer.

(b) Backfilling operation

The mixture to be used in bituminous patching shall be either a hot mix or cold mix. Mixture shall be done in a plant of suitable capacity. The bituminous mixture shall be placed in layers of thickness not more than 100 mm (loose) and shall be compacted in layers with roller/plate compactor/hand roller/rammer to the compacted in layers with roller/plate compactor/hand roller/rammer to the compaction standards . While placing the final layer, the mix shall be spread slightly proud of the surface so that after rolling, the surface shall be flush with the adjoining surface. If the area is large, the spreading and levelling shall be done using hand shovels and wooden edges. Where required, a seal coat shall be applied. During the process of compaction, the surface levels shall be checked using a 3 m straight edge.

Crack sealing

(a) Fine cracks less than 3 mm in width

Sealing of fine cracks shall be done by applying Fog Seal. Fog Seal is a very light application of low viscosity Slow Setting Emulsion, for sealing cracks less than 3 mm in width. The surface on which the fog spray is to be applied shall be thoroughly cleaned with compressed air, scrubber,s etc. The cracks shall be cleaned with a pressure

air jet to remove all dirt, dust, etc. The fog spray shall be applied at a rate 0.5-1.0 litres/m^2 of the specified quantity of emulsion, using equipment such as pressure tank, flexible hose and spray bar or lance. For sites at sub-zero temperature, crack sealing by Medium Curing Cutback as per IS:217 shall be permissible.

(b) Wide cracks

For wider cracks, in excess of an average of 3 mm in width, the application of emulsion may be preceded by an application of crusher dust or other fine material acceptable to the Engineer. The bituminous emulsion for use in crack sealing shall be of a low viscosity Slow Setting type (SS grade). For sites at sub-zero temperature, the use of Medium Curing Cutback as per IS:217 shall be permissible. Dust for crack filling when used, shall be crusher dust or some other fine material, approved by the Engineer, passing 4.75 mm sieve. Dust or other suitable fine material shall be placed in the cracks before the application of binder and the cracks filled to a level approximately 5 mm below road surface level. The surface of the road shall be swept clear of dust prior to the application of binder. Binder shall be poured into the cracks, taking care to minimize spillage. If spillage onto the road surface does occur, dust shall be applied to the excess bitumen until it is blotted up.

6.10. PRIME COAT

6.10.1 Methodology

1. Prior to applying the primer, the surface shall be carefully swept or brushed, clear of dust and loose particles. The existing surface shall be made slightly damp in case of using emulsion.

2. The bitumen primer should normally be emulsion (slow setting.) It should be bituminous emulsion of SS1 type as described in MoRD specifications. Spraying of primer shall be done only with bitumen pressure sprayer. Use of hand sprayer strictly prohibited.

3. Normal temperature range of spraying emulsion should be 20^0C to 60^0C . The rate of application depends upon type of surface to be primed. A very thin layer of clear and may be applied to the surface of primer to prevent the primer picking up under the wheels of the paver and the trucks delivering bituminous material for the construction.

4. Primed surface shall be allowed to cure for at least 24 hrs

6.11. TACK COAT

6.11.1 Methodology:

1. The surface on which the tack coat is to be applied shall be clean and free from dust, dirt, and any extraneous material. Immediately befor ethe application of the tak coat, the surface shall be swept clean with a machanical broom.

2. The bituminous binder should be bituminous emulsion (Rapid setting). The use of cutback (BC – 70 or MC – 70) should not be used. The type of emulsion will be bitumen emulsion of RS1 type as described in MORD specifications.

3. The surface to be tack coated must be clean, free of loose material and dust.

4. The binder should be sprayed uniformly over the surface using suitable bitumen pressure distributor, spraying bitumen at specified rates and temperature so as to provide a uniformly unbroken spread of bitumen. Normal range of spraying

temperature should be 20^0 C -60^0 C in case of emulsion and 50^0 C – 80^0 C in case of cutback.

5. Tack coat shall be left to cure until volatiles have evaporated before any subsequent construction is started.

6.12. SURFACE DRESSING:

1. The base on which the surface dressing is to be laid shall be prepared, shapped and conditioned to the specified lines, grade and cross sections. The bituminous suface to be dressed shall be thoroughly cleaned either by using a machanical broom and/or compressed air, or any other aproved equipment. The prepared surface shall be dust free, clean and dry (except in the case of cationic emulsion where the surface shall be damp.

2. The application temperature for the grade of binder used shall be as given in Table. When bitumen emulsion is used as the binder, it shall be sprayed/distributed uniformly over the prepared base, using self-propelled or towed sprayer, capable of supplying the binder at specified rates so as to provide a uniformly unbroken spread of binder.

Table : 6.2. Spraying Temperatures for Binders

Binder Grades	Whirling Spray Jets		Slot Jets	
	Min ºC	Max ºC	Min ºC	Max ºC
Penetration grades 80/800	180	200	165	175
180/200	170	190	155	165

3. Immediately after application of the binder, clean, dry chips (in the case of emulsion binder the chippings may be damp) shall be spread uniformly on the surface so as to cover the surface completely with a single layer of chips.

4. Rolling of the chips shal be carried out by 60 to 80 kN stactic weight roller, preferably by a pneumatic tyred roller. Rolling shall commence at the edges and

progress towards the centre, except in superelevated and uni-directional cambered protion where it shall proceed from the lower edge to the highter edge. Each pass of the roller shall uniformly overlap no less than one-thid of the track made in the preceding pass. Rolling shall continue until all aggregate particles are firmly embedded in the binder and present a uniform closed surface.

5. Where suface dressing in two coasts is specified, the second coat should not be applied unitil the first coat has been open to traffic for 2 or 3 weeks. The surface on which the second coat is laid must be clean and free of dust. The construction operations for the second coat shall be the same as described as described above.

6.13.PREMIX CARPET AND SEAL COAT

6.13.1 Methodology:

1. The base on which premix carpet (20 mm thick) is to be laid should be prepared and shaped to specified lines, grade and cross sections.

2. A prime coat should be followed by tack coat and it should be applied over the base prepared for laying of the carpet.

3. The temperature of bitumen at the time of mixing should be in the range of 150^0 C to 163^0 C and that of aggregate 155^0 C to 163^0 C provided that the difference in temperature between the binder and aggregate at no time exceeds 14^0 C. Mixing should be thorough to ensure that a homogeneous mixture is obtained and all particles of aggregates are coated uniform. The temperature at the time of discharge of the mixture should be between 130^0 C and 160^0 C.

4. The mixed material should be transported quickly to site of work and laid uniformly by suitable means.

5. The rolling should commence with 80-100 KN rollers degree (three wheels of tandem type), beginning from the edge and progressing towards the centre longitudinally. (On super elevated portions, rolling should progress from lower to upper edge parallel to centre line of pavement). Any high spots or depressions noticed after the roller has passed over the whole area once should be corrected

by removing or adding premixed material. Rolling should recommence thereafter. Each pass should have en overlap of at least one-third of the track made in the proceeding pass. Rolling should continue until entire surface has been rolled to required compaction. The entire operation of rolling shall be completed before the temperature of mix falls below 100°C.

6.14. Seal Coat:

1. A seal coat should be applied to the surface immediately after laying the carpet. The Traffic should not be allowed on the road till seal coat is properly laid and compacted.

2. The mix for the seal coat should be transported quickly to the site of work and spread uniformly on the premix carpet to be sealed. Rolling operations should be undertaken and continued till all voids are sealed and a smooth uniform surface is achieved. The rolling shall start from outer edge and continued up to center so that camber is not disturbed. In case of type A seal coat, the road may be opened to traffic after 24 hours of the work of laying seal coat is completed. In case of seal coat type B or type C the traffic can be allowed after final rolling is complete and temperature of the surface has cooled down to the surrounding temperature.

6.15. Bituminous Macadam

1. The base on which bituminous macadam is to be laid shall be prepared, shaped and compacted to the requied profile

2. Bituminous Macadam shall be prepared in a hot mix plant of adequate capacity uniform quality with thoroughly coated aggregates. The difference in temperature betwwn the binder and aggregate should at no time exceed 14°C. A batch type or continuous type or a spot mixer may be used for preparation of mix

3. Bituminous Macadam shll be transported in clean insulated vehicles and unless otherwise agreed by the Engineer, shall be covered while in trainsit or awaiting tipping.

4. Premixed bituminous macadam shll be spread, levelled, and tamped by an approved self-propelled paveing machine.

5. After the spreading of mix, rolling shall be done by 80 to 100 kN static weight rollers or other approved equipment. The roller shll move at a speed not more than 5 km/hr. Rolling shall commence at the edges and progress towards the centre longitudinally except that on superelevated and uni-directional cambered portions, it shall progress from the lower to the upper edge parallel to the centreline of the pavement.

6. Rolling operations shall be completed in every respect before the temperature of the mix falls below the rolling temperature given in Table 6.3.

Table : 6.3. Manufacturing and Rolling Temperatures

Bitumen Penetration	Bitumen Mixing(°C)	Aggregate Mixing(°C)	Mixed Meterial (°C)	Laying (°C)	Rolling (°C)
35	160-170	160-175	170 maximum	140 maximum	10 maximum
65	150-165	150-170	165 maximum	130 maximum	100 maximum
90	140-160	140-165	155 maximum	130 maximum	100 maximum

6.16.MODIFIED PENETRATION MACADAM

6.16.1.Methodology:

1. The base on which modified penetration macadam course is to be done should be prepared and shaped to the specified lines, grade and cross section

2. A prime coat should be applied over the preparatory base and tack coat shall be applied.

3. The coarse aggregates 40 mm size should be spread uniformly at the rate of 0.9 cum for 75 mm thickness (0.60 cum for 50 mm thickness) per 10 m^2 area over the width of road correct camber/superelevation. Any irregularities shall bt made good by adding aggregates in cas of depressions and removing aggregates from high spots checked with camber board and straight edge batten, etc.

4. Rolling should commence with 80-100 KN rollers (three wheels or tandem type), beginning from the edge and progressing towards the centre longitudinally. (On

super elevated portions rolling should progress from lower to upper edge parallel to centre line of pavement).

5. Any irregularities, noticed after the roller has passed over the whole area once, should be corrected by loosening the surface and removing or adding the coarse aggregates followed by rolling. Rolling should continue till the entire surface has been rolled to desired compaction such that there is no crushing of aggregates and all roller marks have been eliminated.

6. The bitumen should be heated to a temperature of 160^0 C to 180^0 C and sprayed uniformly on aggregate layer at the rate of 20 Kg per 10 m^2 for 75 mm thick layer.(17.5 Kg per 10 m^2 for 50 mm thick layer).

7. Immediately after application of bitumen,12mm size key aggregates should be spread at a uniform rate of 0.18 cum for 75 mm thickness (0.12 cum for 50 mm thickness) per 10 m^2 so as to cover the surface completely followed by rolling. Rolling should continue until the key aggregates are firmly embedded in position.

8. A wearing coat should be applied within a maximum of forty eight hours after laying the modified penetration macadam. If there is any delay in laying of wearing course, a seal coat should be applied before it is open to traffic.

6.17. Shoulder :

1. The sequence of operations shall be such that the construction of shoulders is done in layers, each matching the thickness of adjoining pavement layer. Only after a layer of pavement and corresponding layers in hard and earthen shoulder portion have been laid and compacted (100 per cen of Maximum Dry Density), the construction of next layer of pavement and shoulder shall be taken up.

2. Where the materials in adjacent layers are different, these shall be laid together and the pavement layer shall be compacted first. The adjacent layers having same material shall be laid and compacted together.

3. In all cases where hard shoulders have to be provided along side of existing carriageway, the existing shoulders shall be excavated in full width and to the required depth. Under no circumstances, box cutting shall be done for construction of shoulders.

Note : Maximum laboratory dry unit weight of the material for the shoulder shall not be less than 16.5 KN/m^3. Plasticity Index and Liquid limit shall not exceed 6 and 25 respectively.

Table : 6.4

CHOICE OF TECHNOLOGY FOR RURAL ROADS

S. No.	Item of Work	Tools/ Equipment Suitable			Recommended Technology for Rural Roads
		Labour Based Technology	Intermediate Technology	Equipment Oriented Technology	
1.	Clearing and grubbing	Pickaxe, Hoe, hand shovel, saw, plough	Rippers towed by agricultural tractor	Dozers, Rippers attached to Dozers	Labour based technology is quite efficient, generates employment, is cheap and hence recommended.
2.	Excavation for borrowing soil or natural gravel for embankment/ sub-base/ base construction	Pickaxe, Hoe, hand shovel	Rippers towed by agricultural tractor	Excavator, Dozer, Shovel, Scraper	Labour based technology is quite efficient, adequate for the small volume of work, generates employment, is cheap, and hence recommended.
3.	Excavation in soft rock	Pickaxe, Crowbar Wedging tools	–	Dozer, Ripper, Excavator	Labour based technology is quite efficient, adequate for the small volume involved, generates employment, is cheap and hence recommended.
4.	Excavation in hard rock	Hand drilling and blasting	–	Air compressor, Jack hammers, and blasting	For small jobs, hand drilling and blasting is adequate. For large jobs, use of equipment is recommended.
5.	Loading and unloading of earth, natural gravel, stone materials	Shovel, Hoe,	Shovel, Hoe,	Loader	Manual methods are adequate for the small quantities involved, because of employment generation and relatively low cost.
6.	Hauling of earth, natural gravel, stone materials				
	1) Lead 0-100m	Head basket and wheel barrow	–	–	Labour based technology is recommended.
	2) Lead 100-1000m	Pack animals	Animal cart, agricultural tractor-trailer, trucks	Scraper, Loader, Dumper, Trucks,	Labour-based or intermediate technology is recommended.
	3) Over 1Km	–	Agricultural tractor-trailer, trucks	Scraper, Loader, Dumper	Intermediate technology is recommended.
7.	Spreading of soil or pavement materials in layers	Hoe, Rake	Blader attachment towed by agricultural tractor	Grader, Dozer	Manual method or intermediate technology is recommended.
8.	Breaking clods for soil stabilisation	Wooden Mallet	Disc harrow or ripper towed by agricultural tractor	Disc harrow, ripper towed by dozer or tractor	Intermediate technology using agricultural implements is recommended.

S. No.	Item of Work	Tools/ Equipment Suitable			Recommended Technology for Rural Roads
		Labour Based Technology	Intermediate Technology	Equipment Oriented Technology	
9.	Watering	Watering cans	Water Bowser towed by agricultural tractor	Self propelled Water Tanker	Intermediate technology using a water bowser towed by an agricultural tractor is recommended.
10.	Mixing stabiliser like lime/ cement and soil	Hoe, rake	Disc harrow and ripper towed by agricultural tractor	Single pass Stabiliser	Intermediate technology using agricultural implements towed by agricultural tractor is recommended because of its low cost.
11.	Production of stone aggregates				
	1) For Water Bound Macadam	Hammer	Mobile crushing plant with manual loading `	Crushing Plant with screens, conveyors and loaders	Manual breaking of stones is recommended for small jobs. For larger jobs, small mobile crushing plants are recommended.
	2) For Wet Mix Macadam, Concrete and bituminous surfacing	Not recommended	Mobile crushing plant with manual loading	Crushing plant, screens, conveyors and loaders	Intermediate Technology using mobile crushing plant and manual loading is recommended.
12.	Compaction of earthwork sub-base, WBM and aggregate base	Rollers pulled by animals or human labour	8/10 T Static Smooth Wheel Roller	Vibratory Roller	8/10 T Static smooth wheel roller is recommended.
13.	Prime Coat/ Tack Coat	Hand held cans with holes	Hand held lance provided with a sprayer, operated by compressor	Self propelled Bitumen Pressure Distributor	Intermediate technology using hand held lance with a sprayer and operated by compressor or hand pump is recommended.
14.	Application of binder for surface dressing				
	i) Emulsion	Hand held cans with holes	Hand held lance with sprayer, operated by compressor	Self propelled Bitumen Pressure Distributor	Hand held lance with sprayer, operated by compressor or hand pump is recommended.
	ii) 80/100 Pen. Grade Bitumen	Hand held cans with holes	Hand held lance with sprayer, operated by compressor	Self propelled Bitumen Pressure Distributor	Hand held lance with sprayer, operated by compressor or hand pump is recommended.
15.	Heating Bitumen	Bitumen Boiler of	Bitumen Boiler of	High capacity	Bitumen boiler of small capacity is recommended.

S. No.	Item of Work	Tools/ Equipment Suitable			Recommended Technology for Rural Roads
		Labour Based Technology	Intermediate Technology	Equipment Oriented Technology	
		small capacity	small capacity	bitumen tanks	
16.	Bitumen Premix Carpet	Not recommended	Mini-Hot Mix Plant of 6T capacity	Mobile Hot Mix Plant of 20T capacity	Mini Hot Mix Plant of 6T capacity is recommended.
17.	Application of chips for surface dressing	Manual, by basket, and spreading by rakes	Spreader box towed by agricultural tractor	Self propelled Chip spreader	Manual or intermediate technology is recommended.
18.	Laying of Premix Carpet	Manual, by rakes	Manual by rakes	Paver Finisher	Manual spreading by rakes is recommended.
19.	Rolling of	Hand operated Roller			
	i) Chips for surface dressing	Not recommended	8/10T static smooth wheel roller	8/10T static smooth wheel roller	8/10T static smooth wheel roller is recommended
	ii) Premix Carpet	Not recommended			
20.	Production of Cement Concrete	Hand mixing Not recommended	Small concrete mixers, with weighing facility	Small Batching Plants	Small concrete mixers with weighing facility are recommended
21.	Vibration of concrete	Rodding Not recommended	1) Needle vibrators 2) Screeds for concrete pavement 3) 8/10T` Roller for Roller Compacted Concrete.	1) Needle vibrators 2) Screeds 3) Vibratory Roller for Roller Compacted Concrete.	1) Needle vibrators for RCC slabs, beams, mass concrete 2) Screeds for concrete pavement 3) 8/10T static roller or vibratory roller for Roller Compacted Concrete

Table: 6.5. Tentative output of road machinery

1.	Scraper (Motorised) towed	160 cum/day
2.	Dozer	200 cum/day
3.	Motoer Grader	600 cum/day
4.	Excavator 1m^3 capacity	400 cum/day
5.	Three smooth wheeled road roller output a) Earth work b) Moorum/Gravel c Pavement i) WBM Stone base course ii) WBM/WMM wearing course iii) DBM d) Surfacing Dressing i) First Coat ii) Second Coat e) Premix Carpet i) 25 mm thick ii) 20 mm thick	 450 cum/day 450 cum/day 45 cum/day 40 cum/day 40 cum/day 2500 sqm/day 3500 sqm/day 2000 sqm/day 2000 sqm/day
6.	Earthwork compaction by sheep foot road roller	600 cum/day
7.	Vibratory road roller earth-work (depends upon the thickness) of layer and type	600 cum/day
8.	Other machinery a) Mini Hot Mix Plant 6-10 TPH b) Hot Mix Plant 40-60 TPH c) Paver Finishers 75-160 TPH d) Bitumen Boiler e) Water Tankers f) Bitumen Pressure Distributors g) Wet Mix Macadam Plant 60 T/Hr. h) Stone Crusher less than 100 Ton/hr.	 8 Ton/hr. 50 Ton/hr 75 Ton/hr 2000 Litre/hr. 10,000 Litres 10,000 Litres 50 Ton/hr. Depending upon the requirment

	i) Multi stage stone crusher more than j) Concrete Batching Mix/Plant upto 50 cum/hr. k) Concrete Batching Mix Plant more than 50 cum/hr	100 Ton/hr. 40 cum/hr. Depending upon the requirment
9.	Convenyace by trucks/tippers When lead = 2 kilometres, trips per day When lead = 8 kilometres, trips per day When lead = 16 kilometres, trips per day When lead = 30 kilometres, trips per day Note : No. of working days per year	 8 nos. 6 nos. 5 nos. 4 nos. 200

6.18. STAGES IN CONSTRUCTION OF A ROAD:

6.18.1 FORMATION OF ROADS:

a. Earth work should be rolled layer by layer with specified water content by using power roller. Compaction may be checked at field by sand replacement method or core cutter method.

b. Proper Camber and Super elevation should be maintained right from embankment construction.

c. Continuous Kutcha / Pucca drain should be provided on both sides.

d. Thickness of sub grade layer may be checked at regular intervals.

e. Embankment height should be more than 0.60m to 1.00 m from the water table level.

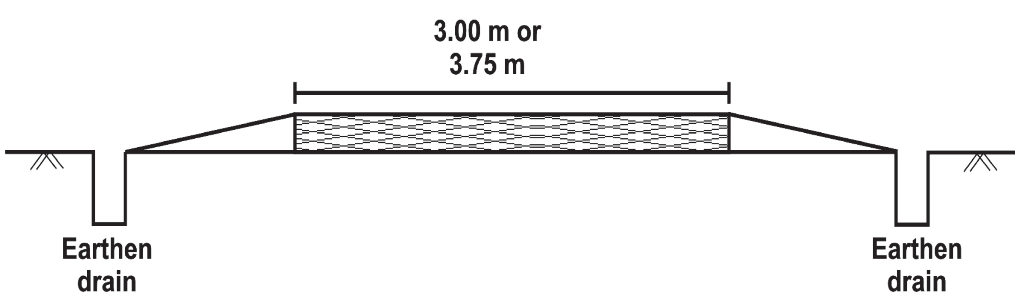
f. Proper slope (1.5:1 / 2:1 based on soil condition) should be maintained.

6.18.2. Important Instructions in Road Formation :

- Name board indicating the scheme details to be placed at starting point of the road

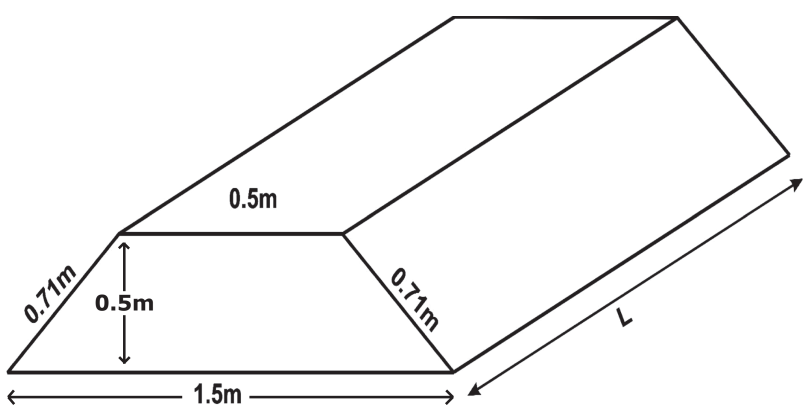
- Whether proper drainage facility / Cross drainage is provided to the road
- Both sides of the drains should be uniform and parallel
- Whether the required land width is available
- Whether proper camber and super elevation is provided in the road
- Whether proper compaction is provided for earth work
- Location of the CD works may be justified in the site.
- To check no silting is accumulated in the culvert
- To check undulations in the road surface
- Rocky outcrops and uprooting for the trees should be checked.
- HM and KM stone should be verified.
- Top level of the formation should be 0.75 m above adjacent ground level.
- Alignment of the road as far as possible should be straight according to site conditions.
- Photographs (before formation stage) may be compared to determine the new formation.

Cross Section Formation Road



6.18.3 IMPORTANT INSTRUCTIONS IN WBM CONSTRUCTION:

- Name board indicating the scheme details to be placed at starting point of the road.
- Check the width of the road at random interval.
- The metal collected should be of the following size.
  - o Ist Layer WBM - 90mm to 22.40mm size metal
  - o IInd Layer WBM - 63mm to 11.20mm size metal
- Sieve test should be conducted at site to determine the size and distribution of the metal.
- The metal should be of good quality, free from dust and it should not be flaky, soft and rounded.
- The requirement of metal for roads are
  - o For 3.75m width - 375.00m^3 per km.
  - o For 3.00m width - 300.00m^3 per km.
- The metal should be stacked at the site for premeasurement with specified dimensions. The dimension of each stack should be like this.



Volume of Stack per meter run = $\dfrac{(1.50 + 0.50)}{2}$ **x 1.00x0.50 = 0.5 cum**

- Camber should be provided. (Camber is nothing but the fall of the road from the centre of road towards the road edge on both the sides)
- At curves super elevation is to be provided. Super elevation is nothing but the raised outher edge with respect to inner edge to avoid the over turning moment due to centrifugal force.
- The unscreened gravel should also be simultaneously collected along with metal for blindage.
    - The required quantities of the gravel are as follows:

      For 3.75 m width - 90 m^3 per km

      For 3.00 m width - 72 m^3 per km
- The WBM surface should be rolled with 8 – 10 tonnes power roller for proper consolidation with water.
- Berms may be strengthened with Earth or Gravel for the specified thickness as in the estimate. Simultaneous compaction should be done along with the pavement.
- The WBM surface should be even without undulations.
- For each layer the compacted thickness of the WBM must be 75mm.
- Culverts, retaining walls should be completed before laying WBM.
- The thickness of the WBM layer may be verified by digging the pavement.

6.18.4 IMPORTANT INSTRUCTIONS IN BT ROAD CONSTRUCTION:

- Name board indicating the scheme details to be placed at starting point of the road.
- For Premix Carpet the metal size should be 13.20mm and 11.20mm.
- For seal coat, the size of the metal should be 6.70mm.
- Sieve test may be conducted to check the metal size.
- Hard Broken Granite crusher metal to be used for Bitumen roads. It should be free from dust and other foreign materials.
- Metal should be stacked for pre measurement.
- Metal requirement
  - 13.20 and 11.20mm metal
    - For 3.75 m width - 101.25 m^3 per km
  - 13.20 and 11.20mm metal
    - For 3.00 m width - 81.00 m^3 per km
- Metal requirement for seal coat
  - 6.70 mm metal
    - For 3.75 m width - 101.25 m^3 per km
  - 6.70 mm metal
    - For 3.00 m width - 27.00 m^3 per km
- Width and length of the road may be checked with reference to relevant records.
- Emulsion bitumen should be used for tack coat.
- Emulsion requirement (200 Kg / Drum)

- Over WBM surface
  - 3.75 m width - 1500 kg per km
  - 3.00 m width - 1200 kg per km
- Over BT surface
  - 3.75 m width - 1125 kg per km
  - 3.00 m width - 900 kg per km.

- Bitumen requirement (156 kg / Drum) or (161.8 kg / Drum)
  - 3.75 m width - 9150 kg per km
  - 3.00 m width - 7320 kg per km
- The finished compacted thickness of the BT surface should be 20mm.
- Specified Bitumen grade should be used at site 60/70 (or) 80/100. Grade of bitumen may be checked with the purchase invoice.
- The BT surface rolled with 8 – 10 tonnes power roller for proper consolidation.
- The final product of the BT surface will be even and without undulations.
- Edge packing of the road edges should be done with earth / gravel.

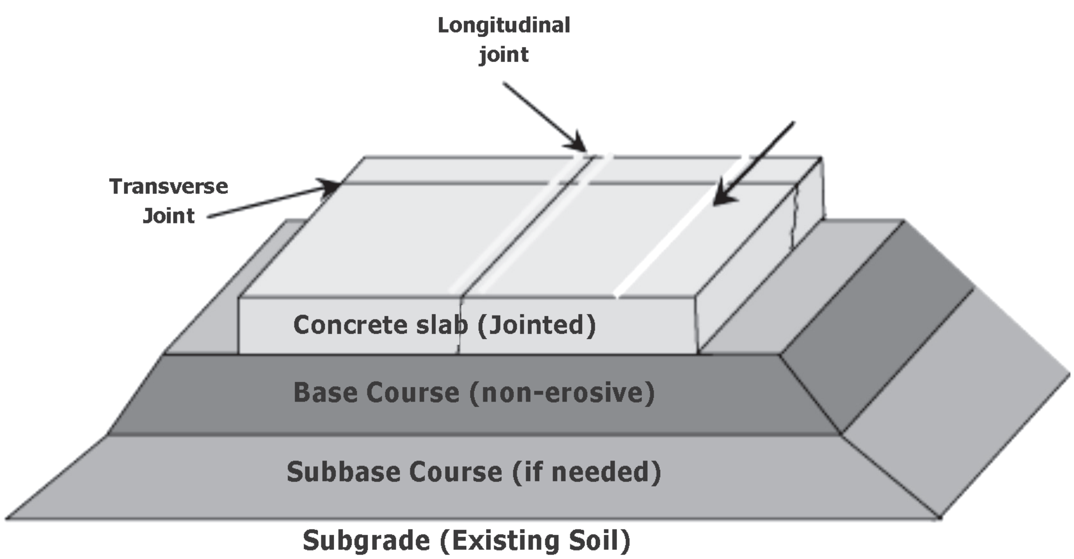
RIGID PAVEMENT DESIGN

7. RIGID PAVEMENT DESIGN

7.1. INTRODUCTION

In spite of vigorous attempts over the past fifty years, a large proportion of India's villages remain unconnected by an all-weather road. Renewed efforts are now being made to overcome this deficiency. It is observed that rural roads have a very low volume of traffic, generally of the order of less than 150 vehicles per day, consisting mostly of rural transport vehicles like agricultural tractors/trailers, light goods vehicles, buses, animal drawn vehicles, motorised two-wheelers and cycles. Some of the rural roads may also have light and medium trucks carrying sugarcane, timber, quarry materials etc. Another feature common to rural roads is that their maintenance is neglected, because of paucity of funds and poor institutional set-up. The design of pavements for rural roads should recognise these factors.

Concrete pavements offer an alternative to flexible pavements especially where the soil strength is poor, the aggregates are costly and drainage conditions are bad (as in portions of the roads passing through villages and water-logged areas). The choice depends on these factors and the life-cycle cost. Concrete pavements may be conventional screed-compacted pavements, Roller Compacted Concrete Pavements (RCCP) or Interlocking Concrete Block Pavements (ICBP).



Cross section of Rigid Pavement

7.2. FACTORS GOVERNING DESIGN

7.2.1. WHEEL LOAD

The legal axle load in India being 102 kN, the pavement may be designed for a wheel load of 51 kN. However, for link roads serving isolated villages where the chances of heavy trucks operating are non-existent, a design wheel load of 3 kN may be considered.

7.2.2. TYRE PRESSURE

The tyre pressure may be taken as 0.7 MPa where a wheel load of 51 kN is considered and 0.5MPa where a wheel load of 30 kN is considered.

7.2.3. DESIGN PERIOD

The design methodology given in these guidelines is based on wheel load stresses. The repetitions of wheel loads and the consumption of fatigue, which form the basis of design in IRC:58-2002, need not be considered for the very low volume of traffic encountered on rural roads. Concrete pavements designed and constructed as per the guidelines contained in this document will have a life of not less than 20 years, as evidenced from the performance of roads constructed in the past in the country.

7.2.4. CHARACTERISTICS OF THE SUBGRADE

The strength of subgrade is expressed in terms of modulus of subgrade reaction, k, which is determined by carrying out a plate bearing test, using of 750 mm dia. plate according to IS: 9214-1974. In case of homogeneous foundation, test values obtained with a plate of 300 mm dia, k300, may be converted to give k750, determined using the standard 750 mm dia plate by the following correlation:

$$k_{750} = 0.5\ k_{300} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

Since the subgrade strength is affected by the moisture content, it is desirable to determine it during or soon after the rainy season. An idea of the k value of a homogeneous soil sub-grade may be obtained from its soaked CBR value using Table 7.1.

Table. 7.1. Approximate k value corresponding to CBR values

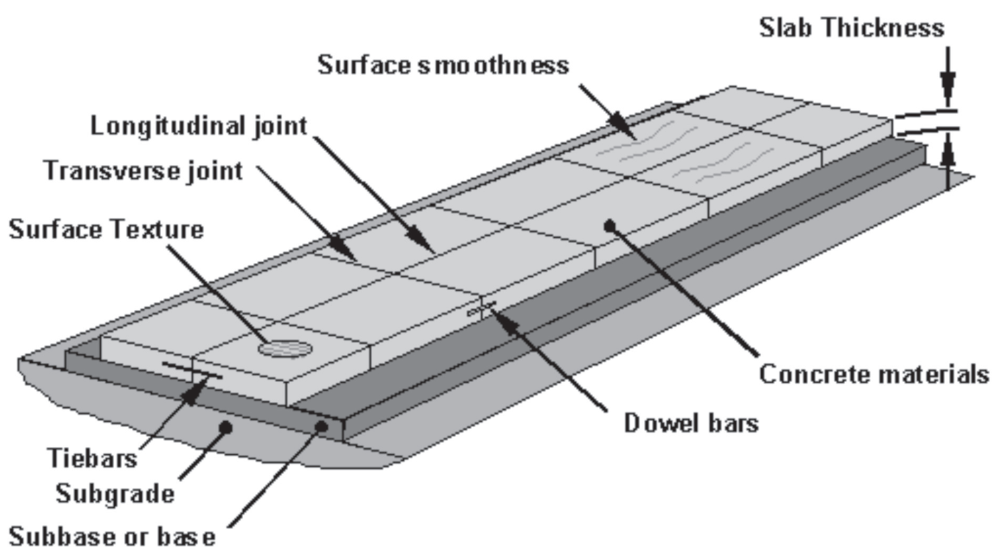
CBR%	2	3	4	5	7	10	15	20	50
k Value (×10-3) N/mm2/mm	21	28	35	42	48	55	62	69	140

7.3. SUB-BASE

The provision of a sub-base below the concrete pavement has many advantages such as:

1. It provides a uniform and reasonably firm support.
2. It prevents mud-pumping on subgrade of clays and silts.
3. It acts as a levelling course on distorted, non-uniform and undulating sub-grade.
4. It acts as a capillary cut-off.

Where the pavement is designed for a wheel load of 51 kN, a 150 mm thick sub-base of Water Bound Macadam (using 53-22.4 mm aggregates), granular sub-base, gravel, soil-cement or soil-lime may be provided. Where the traffic is light and the pavement is designed for a wheel load of 30 kN, the thickness of the sub-base may be reduced to 75 mm. The WBM and granular sub-base surface shall be finished smooth.



When the above type of sub-base is provided, the effective k value may be taken as 20% more than the k value of the sub-grade.

A plastic sheet of 125 microns thickness shall be provided over the sub-base to act as a separation layer between the sub-base and concrete slab.

7.4. CONCRETE STRENGTH

Since concrete pavements fail due to bending stresses, it is necessary that their design is based on the flexural strength of concrete. Where there are no facilities for determining the flexural strength, the mix design may be carried out using the compressive strength values and the following relationship:

$$f_f = 0.7\sqrt{f_c} \quad ....(2)$$

where ff = flexural strength, N/mm2

fc = characteristic compressive cube strength, N/mm2

If the flexural strength observed from laboratory tests is higher than that given by the above formula, the same may be used.

For Rural Roads, it is suggested that the 90-day strength be used for design instead of the 28-day strength as the traffic develops only after the lapse of a period of time. The 90 day flexural strength may be taken as 1.20 times the 28-day flexural strength or as determined from laboratory tests. Heavy traffic should not be allowed for 90 days.

The concrete mix should be so designed that the minimum flexural strength requirement in the field is met at the desired confidence level. For rural roads, the tolerance level (accepted proportion of low results), can be taken as 1 in 20. The normal variate, Za, for this tolerance level being 1.65, the target average flexural strength is obtained from the following relationship:

$S = S^1 + Z_a\sigma$ .... (3)

where S = target average flexural strength, at 28 days, MPa

S^1 = characteristic flexural strength, at 28 days, MPa

Za = normal variate, having a value of 1.65, for a tolerance factor of 1 in 20.

σ = expected standard deviation of field test samples, MPa

Table 7.2 gives the values of expected standard deviation of compressive strength

Table 7.2. Expected Values of Standard Deviation of Compressive Strength

Grade of concrete	Standard Deviation for different degrees of control, MPa		
	Very good	Good	Fair
M 30	5.0	6.0	7.0
M 35	5.3	6.6	7.3
M 40	5.6	6.3	7.6

The standard deviation of flexural strength may be derived approximately using the formula given earlier.

For pavement construction for rural roads, it is recommended that the characteristic 28-day compressive strength should be at least 30 MPa. The characteristic 28-day flexural strength shall be at least 3.8 MPa.

7.4.1 MODULUS OF ELASTICITY AND POISSON'S RATIO

The Modulus of Elasticity, E, of concrete may be taken as 3.0 x 104 MPa.

The Poissons ratio may be taken as 0.15.

7.4.2 COEFFICIENT OF THERMAL EXPANSION

The coefficient of thermal expansion of concrete α, may be taken as

α = 10 x 10-6 per C.

7.5. CRITICAL STRESS CONDITION

Concrete pavements in service are subjected to stresses due to a variety of factors, acting simultaneously, the severest combination of which inducing the highest

stress in the pavement will give the critical stress condition. The factors commonly considered for design of pavement thickness are traffic loads and temperature variations, as the two are additive. The effects of moisture changes and shrinkage, being generally opposed to those of temperature and are of smaller magnitude, would ordinarily relieve the temperature effects to some extent and are not normally considered critical to thickness design.

For purpose of analysis, three different regions are recognised in a pavement slab-corner, edge and interior which react differently from one another to the effect of temperature differentials, as well as load application.

The concrete pavements undergo a daily cyclic change of temperature differentials, the top being hotter than the bottom during day and cooler during night. The consequent tendency of the pavement slabs to warp upwards (top convex) during the day and downwards (top concave) during the night, and restraint offered to this warping tendency by self-weight of the pavement induces stresses in the pavement, referred to commonly as temperature stresses. These are flexural in nature, being tensile at bottom during the day and at top during night. As the restraint offered to warping at any section of the slab would be a function of weight of the slab up to that section, it is obvious that corners have very little of such restraint. The restraint is maximum in the slab interior, and somewhat less at the edge. Consequently the temperature stresses induced in the pavement are negligible in the corner region, and maximum at the interior.

Under the action of load application, maximum stress is induced in the corner region, as the corner is discontinuous in two directions especially when load transfer steeldowels are not provided in rural roads. The edge being discontinuous in one direction only has lower stress, while the least stress is induced in the interior where the slab is continuous in all directions. Furthermore, the corner tends to bend like a cantilever, giving tension at the top, interior like a beam giving tension at bottom. At edge, main bending is along the edge like a beam giving maximum tension at bottom.

The maximum combined tensile stresses in the three regions of the slab will thus be caused when effects of temperature differentials are such as to be additive to the load effects. This would occur during the day in case of interior and edge regions,

at the time of maximum temperature differential in the slab. In the corner region, the temperature stress is negligible, but the load stress is maximum at night when the slab corners have a tendency to lift up due to warping and lose partly the foundation support. Considering the total combined stress for the three regions, viz., corner, edge and interior, for which the load stress decreases in that order while the temperature stress increases, the critical stress condition is reached in the edge region where neither of the load and temperature stresses are the minimum. It is, therefore felt that both the corner and the edge regions should be checked for total stresses and design of slab thickness should be based on the more critical condition of the two.

7.5.1 CALCULATION OF STRESSES

7.5.1.1. EDGE STRESSES

a) **Due to load:** The load stress in the critical edge region may be obtained as per Westergaard analysis as modified by Teller and Sutherland from the following correlation (metric units):

$$\sigma le = 0.529\,\frac{P}{h^2}\,(1 + 0.54\mu)(4\log_{10}\frac{\ell}{b} + \log_{10} b - 0.4048)$$

where σle = load stress in the edge region, MPa

P = design wheel load, N

h = pavement slab thickness, mm

μ = Poissons ratio for concrete

E = Modulus of elasticity for concrete, MPa

k = Modulus of subgrade reaction of the pavement foundation, N/mm3 ×10-3

○= radius of relative stiffness, mm

$$= \sqrt[4]{\frac{Eh^3}{12(1-\mu^2)k}}$$

b = radius of equivalent distribution of pressure

= a for a/h ≥ 1.724

$$= \sqrt{1.6\,a^2 + h^2} - 0.675 \quad \text{for } a/h < 1.724 \text{ .... (5)}$$

and a = radius of load contact assumed circular, cm

$$= \left(\frac{P}{p\pi}\right)^{1/2} \text{ where p is tyre pressure}$$

(b) Due to temperature: The temperature stress at the critical edge region may be obtained as per Westergaard's analysis, using Bradbury's coefficient from the following correlation:

$$\sigma t_e = \frac{E\,\alpha\,\Delta t}{2} C \text{ .... (6)}$$

where σt_e = temperature stress in the edge region, MPa

Δt = maximum temperature differential during day between top and bottom of the slab, °C

α = Coefficient of thermal expansion of concrete, / °C

C = Bradbury's coefficient, which can be ascertained directly from Bradbury's chart against values of L/l and W/l

L = slab length/ spacing between consecutive contraction joints, m

W = slab width, m

l = radius of relative stiffness, m

Values of C based on the curves given in Bradbury's chart, are given in Table 7.3.

Table 7.3. Values of co-efficient 'C' based on Bradbury's Chart

L/l and W/l	C
1	0.000
2	0.040
3	0.175
4	0.440
5	0.720
6	0.920
7	1.030
8	1.077
9	1.080
10	1.075
11	1.050
12 and above	1.000

7.5.1.2. TEMPERATURE DIFFERENTIAL

Temperature differential between the top and bottom of concrete pavements causes the concrete slab to warp, giving rise to stresses. The temperature differential is a function of solar radiation received by the pavement surface at the location, losses due to wind velocity, etc., and thermal diffusivity of concrete, and is thus affected by geographical features of the pavement location. As far as possible, values of actually anticipated temperature differentials at the location of the pavement should be adopted for pavement design. For this purpose guidance may be had from Table 7.4.

Table 7.4: Recommended Temperature Differentials for Concrete Slabs

Zone	States	Temperature Differential, ^0C in Slabs of Thickness		
		150mm	200mm	250mm
I.	Punjab, U.P., Uttaranchal, Rajasthan, Haryana, Gujarat and North M.P., excluding hilly regions.	12.5	13.1	14.3
II	Bihar, Jharkand, West Bengal, Assam and Eastern Orissa excluding hilly regions and coastal areas.	15.6	16.4	16.6
III	Maharashtra, Karnataka, South M.P., Chattisgarh, Andhra Pradesh, Western Orissa and North Tamil Nadu excluding hilly regions and coastal areas.	17.3	19.0	20.3
IV	Kerala and South Tamil Nadu excluding hilly regions and coastal areas.	15.0	16.4	
V	Coastal areas bounded by hills.	14.6	15.8	
VI	Coastal areas unbounded by hills.	15.5	17.0	
IV	Kerala and South Tamil Nadu excluding hilly regions and coastal areas.	15.0	16.4	

Design Chart for calculation of temperature stress for different values of C is given in Fig. 7.1.

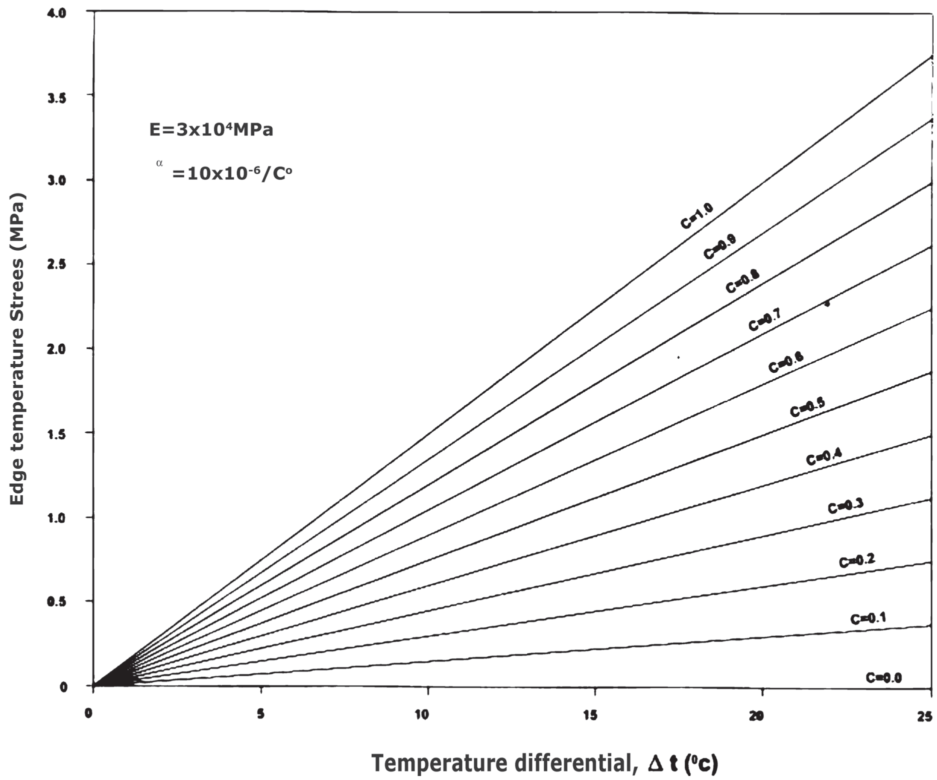


Fig.7.1. Design chart for calculation of temperature stress (IRC:SP:62-2004)

Chart for determination of coefficient C:

L/l or W/l	C	L/l or W/l	C
1	0.000	7	1.030
2	0.040	8	1.077
3	0.175	9	1.080
4	0.440	10	1.075
5	0.720	11	1.050
6	0.920	12 and above	1.000

7.5.1.3 WARPING STRESSES

Whenever the top and bottom surfaces of a concrete pavement simultaneously possess different temperatures, the slab tends to warp downward or upward including warping stresses. The difference in temperature between the top and bottom of the slab depends mainly on the slab thickness and the climatic conditions of the region.

By the time the top temperature increases to t1 degrees, the bottom temperature may be only t2 degrees and the difference between the top and bottom of the slab would be (t1-t2)=t degrees. Assuming straight line variation in temperature across the pavement depth, the temperature at mid depth or average temperature of slab is (t1+t2)/2.

If the slab has no restraint then the unit elongation of the top fibres and also unit contraction of the bottom fibre due to relative temperature condition, each would be equal to Eet/2 where e is the thermal coefficient of concrete. Westergaard worked out the stresses due to the warping of concrete slabs. Now introducing the Poisson's ratio, the stresses at the interior, region in longitudinal and transverse directions as given by Braudbury are expressed by the following equations:

$$St_{(t)} = \frac{Eet\,(C_x + \mu C_y)}{2(1-\mu^2)}$$

where,

$St_{(t)}$ = warping stress at interior, N/mm2

E = modulus of elasticity of concrete, N/mm2

e = thermal coefficient of concrete per degree centigrade

t = temperature difference between top and bottom of the slab in degree C

Cx = coefficient based on Lx/l in desired direction

Cy = coefficient based on Ly/l in right angle to above direction

μ = Poisson's ratio

Lx and Ly are the dimensions of the slab considering along X and Y directions along the length and width of slab.

The warping stresses at the edge region is given by

$$St_{(e)} = C_x Eet/2$$

For corner region, warping stress is given by

$$St_{(c)} = \frac{Eet\sqrt{a/l}}{3(1-\mu)}$$

Here, ‘a’ is the radius of conduct and ‘l’ is the radius of relative stiffness.

7.5.1.4. FRICTIONAL STRESSES

Due to uniform temperature rise and fall in the cement concrete slab, there is an overall expansion and contraction of the slab. Since the slab is in contact with soil subgrade or the subbase, the slab movements are restrained due to the friction between the bottom layer of the pavement and the soil layer. This frictional resistance therefore tends to prevent the movements of the cement concrete pavement. Stresses in the slabs resulting due to this phenomenon vary with slab length. In short, the slab stress induced due to this is negligibly small whereas in long slabs which would undergo movements of more than 1.5 mm, higher amount of frictional stress develops.

Equating total force developed in the cross section of concrete pavement due to movement and frictional resistance due to subgrade restraint in half the length of the slab

$$S_f \times h \times B \times 100 = B \times L/2 \times h/100 \times W \times f$$

$$S_f = \frac{WLf}{2x10^4}$$

Here,

S_f = unit stress developed in cement concrete pavement, N/mm2

W = unit weight of concrete, N/mm2

f = coefficient of subgrade restraint (maximum value is about 1.5)

B = Slab width, m

L = Slab length, m

7.5.1.5. CORNER STRESSES

The load stress in the corner region may be obtained as per Westergaard.s analysis as modified by Kelley, from the following correlation:

$$\sigma_{le} = \frac{3P}{h^2}\left[1 - \left(\frac{a\sqrt{2}}{\ell}\right)^{1.2}\right] \text{........ (7)}$$

where σle = load stress in the corner region, other notations remaining the same as in the case of the edge stress formula.

The temperature stress in the corner region is negligible, as the corners are relatively free to warp, and may be ignored.

7.5.2. DESIGN CHARTS

Figs. 7.2 and 7.3 give ready-to-use design charts for calculations of load stress in the edge and corner regions of rigid pavement slabs for a wheel load of 30 kN. Figs. 7.4 and 7.5 give similar charts for a wheel load of 51 kN.

7.5.3. REINFORCEMENT

Plain concrete jointed slabs for rural roads do not require reinforcement.

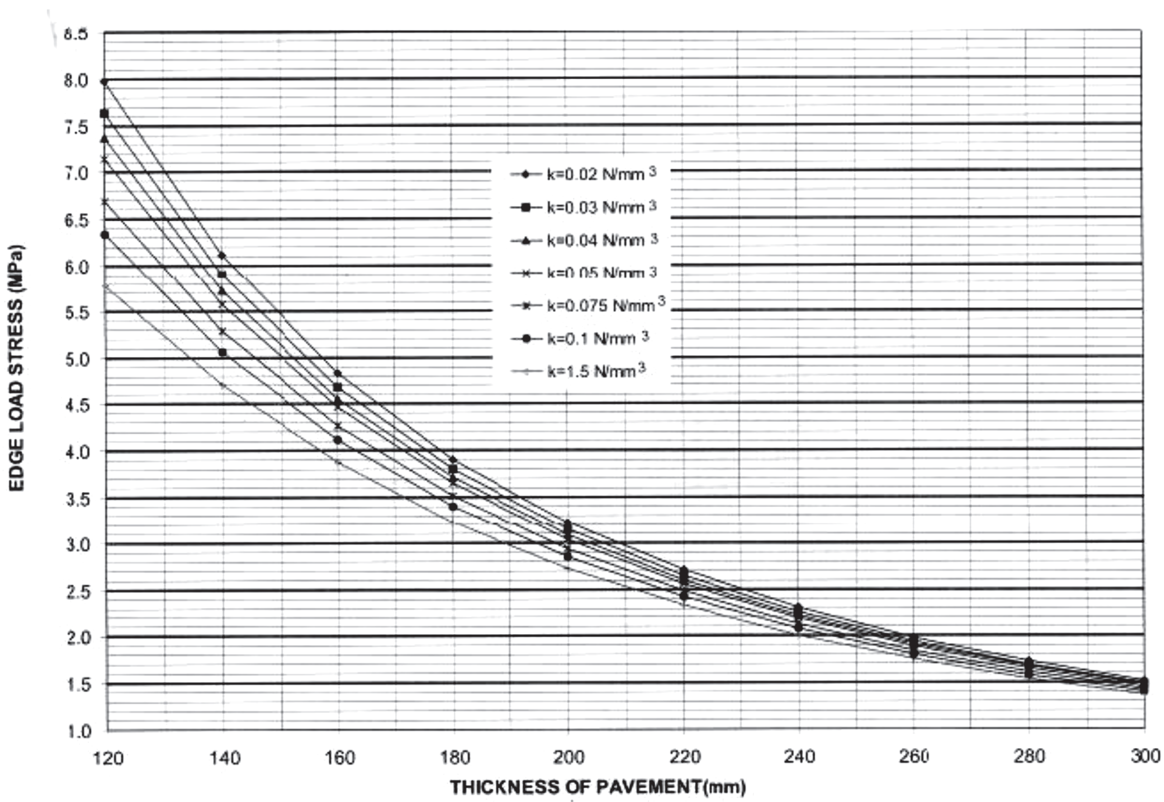


Fig 7.2. Edge load stresses for whell load of 30 KN (IRC:SP:62-2004)

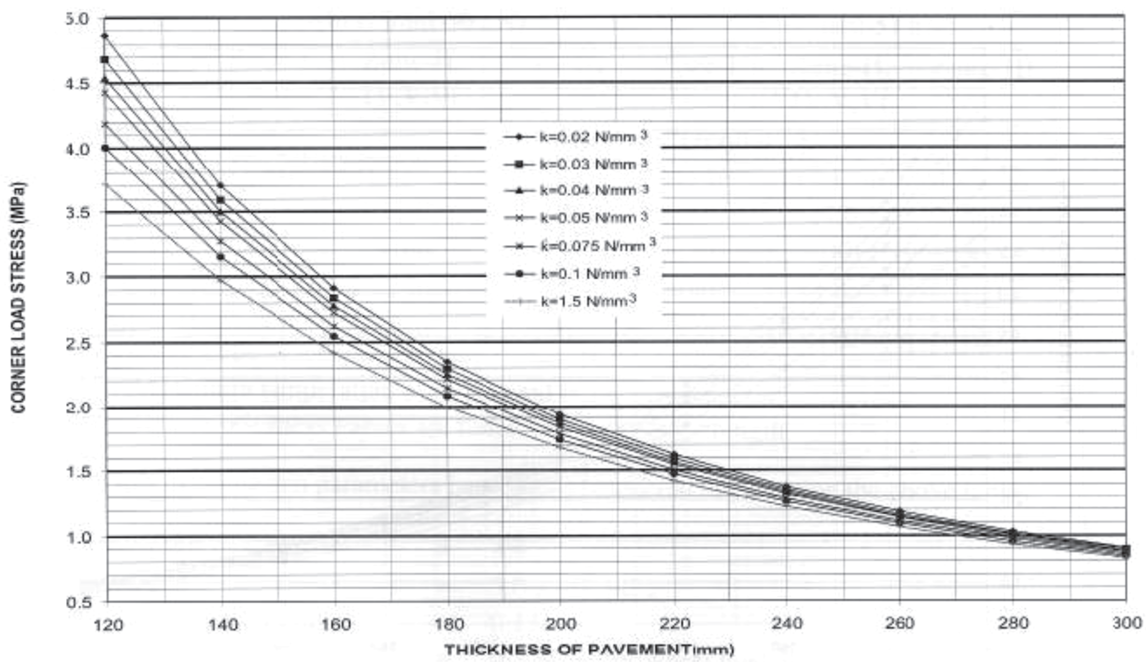


Fig 7.3. Corner load stresses for whell load of 30 KN (IRC:SP:62-2004)

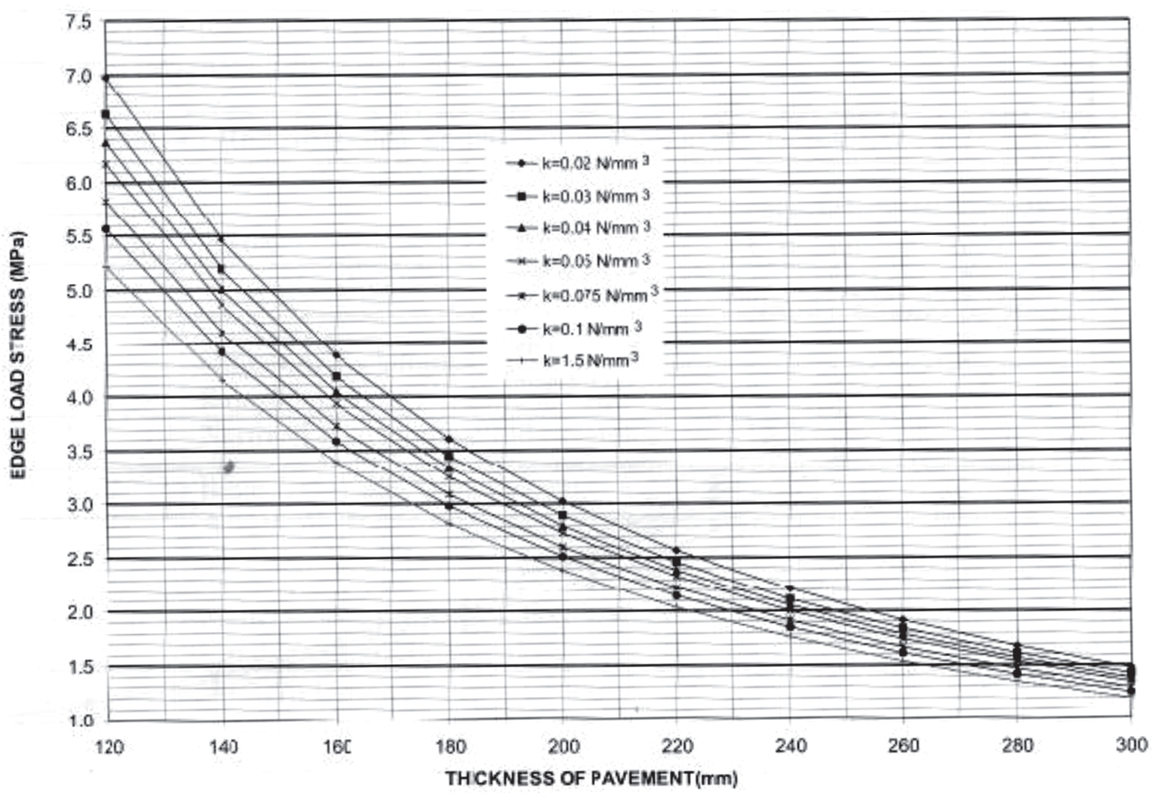


Fig 7.4. Edge load stresses for whell load of 51 KN (IRC:SP:62-2004)

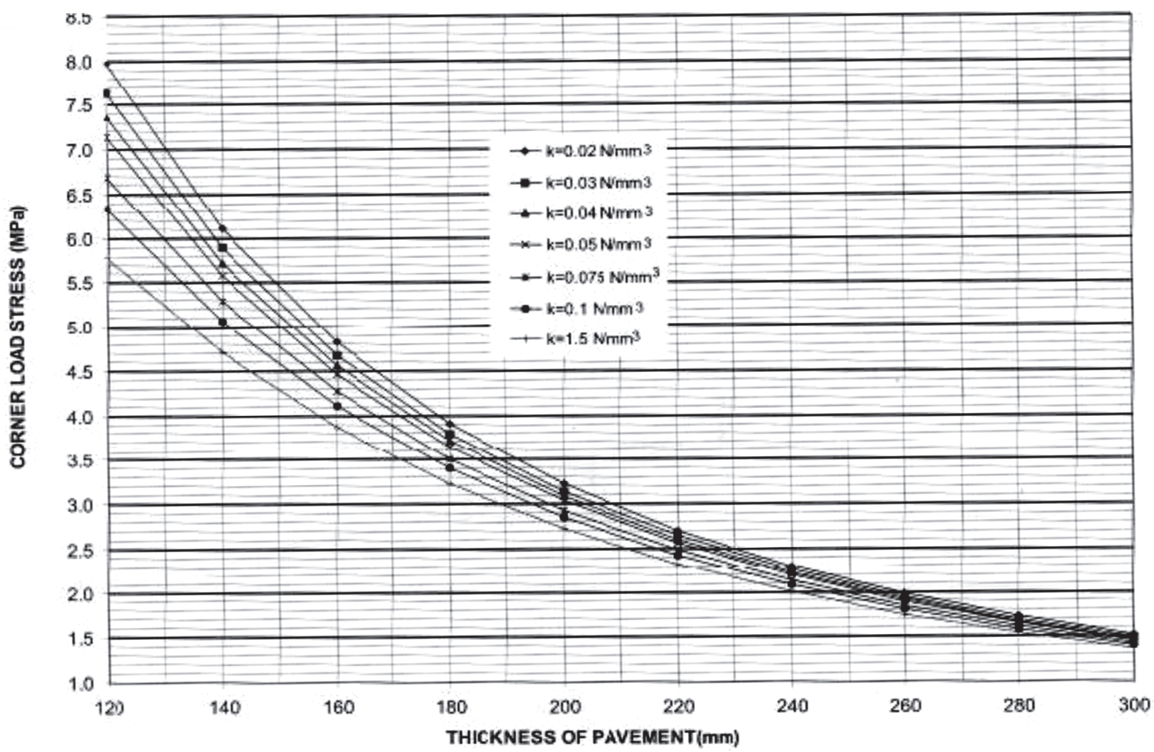


Fig 7.5. Corner load stresses for whell load of 51 KN (IRC:SP:62-2004)

7.6. RECOMMENDED DESIGN PROCEDURE

1. Select design wheel load, concrete flexural strength, modulus of subgrade reaction, modulus of elasticity of concrete, Poisson.s ratio, coefficient of thermal expansion of concrete.

2. Decide joint spacing and lane width

3. Select tentative design thickness of slab, based on defined design load, k value/ CBR and flexural strength of concrete.

4. Ascertain maximum temperature stress for the critical edge region from Equation (6).

5. Calculate the residual available strength of concrete for supporting traffic loads.

6. Ascertain edge load stress from Equation (3) or Fig. 7.2 or Fig. 7.4 as relevant and calculate the factor of safety.

7. In case the available factor of safety is less than or far in excess of 1, adjust the tentative slab thickness and repeat steps 3 to 6 till the factor of safety is 1 or slightly more.

8. Check the adequacy of thickness in the corner region by ascertaining corner load stress from Equation (7) or Fig. 7.3 or Fig. 7.5 as relevant and readjust the thickness if inadequate.

Table 7.5 gives slab thickness for Rural Roads under different traffic and temperature differential conditions for two common types of concrete. The thickness given is applicable to common subgrade soils such as clay, silt and silty clay, with CBR value of 4.

Table 7.5 Concrete Pavement Thickness for Rural Roads

28-Day Concrete Strength (compres-sive) (MPa)	Pavement Thickness(mm)					
	Low Traffic (wheel load-30 kN)			Heavy Traffic (wheel load-51 kN)		
	Zone-I	Zone-II,IV,V,VI	Zone-III	Zone-I	Zone-II,IV,V,VI	Zone-III
	Temperature differential, °C					
	<15.0^{0}	15.1^{0} to 17.0^{0}	17.1^{0} to 20.0^{0}	<15.0^{0}	15.1^{0} to 17.0^{0}	17.1^{0} to 20.0^{0}
30	150	160	170	190	190	200
35	150	150	160	180	180	190
40	150	150	150	170	180	180

Note: 1) Maximum Temperature is considered in the computation

2) Design thickness values are based on the 90-day strength

The following design parameters have been considered in preparing above tables:

CBR	=	4%
E	=	3.0×10^4 MPa
μ (Poisson's ratio)	=	0.15
Tyre pressure	=	0.5 MPa (for wheel load 30 kN) 0.7 MPa (for wheel load 51 kN)
Configuration of slab	=	3.75 m x 3.75 m

7.7. JOINTS

7.7.1. TYPES OF JOINTS

Rural Roads are generally of single lane, and the full lane width (3.0-3.75m) is concreted in one operation. Thus, there is no need for a longitudinal joint for single lane rural roads.

As regards transverse joints, they are of three types:

1. Contraction joints
2. Construction joints
3. Expansion joints

7.7.2. SPACING OF JOINTS

i. Transverse Contraction/ Construction Joints

The spacing of transverse contraction joints or construction joints in alternate bay construction may be kept 2.50 m . 3.75 m. The length of the panel in the direction of traffic shall not be less than the width of the panel. The details of the joint are shown in Fig. 7.6.

ii. Expansion Joints

Expansion joints are necessary where concrete slabs abut with bridges and culverts. The details of the joints are shown in Fig. 7.6.

iii. Longitudinal Joints

Where the width of concrete slab exceeds 4.5 m as in the case of causeways etc, it is necessary to provide a longitudinal joint as per the details given in Fig. 7.6 in the mid-width of the slab.

iv. Load Transfer at Transverse Joints

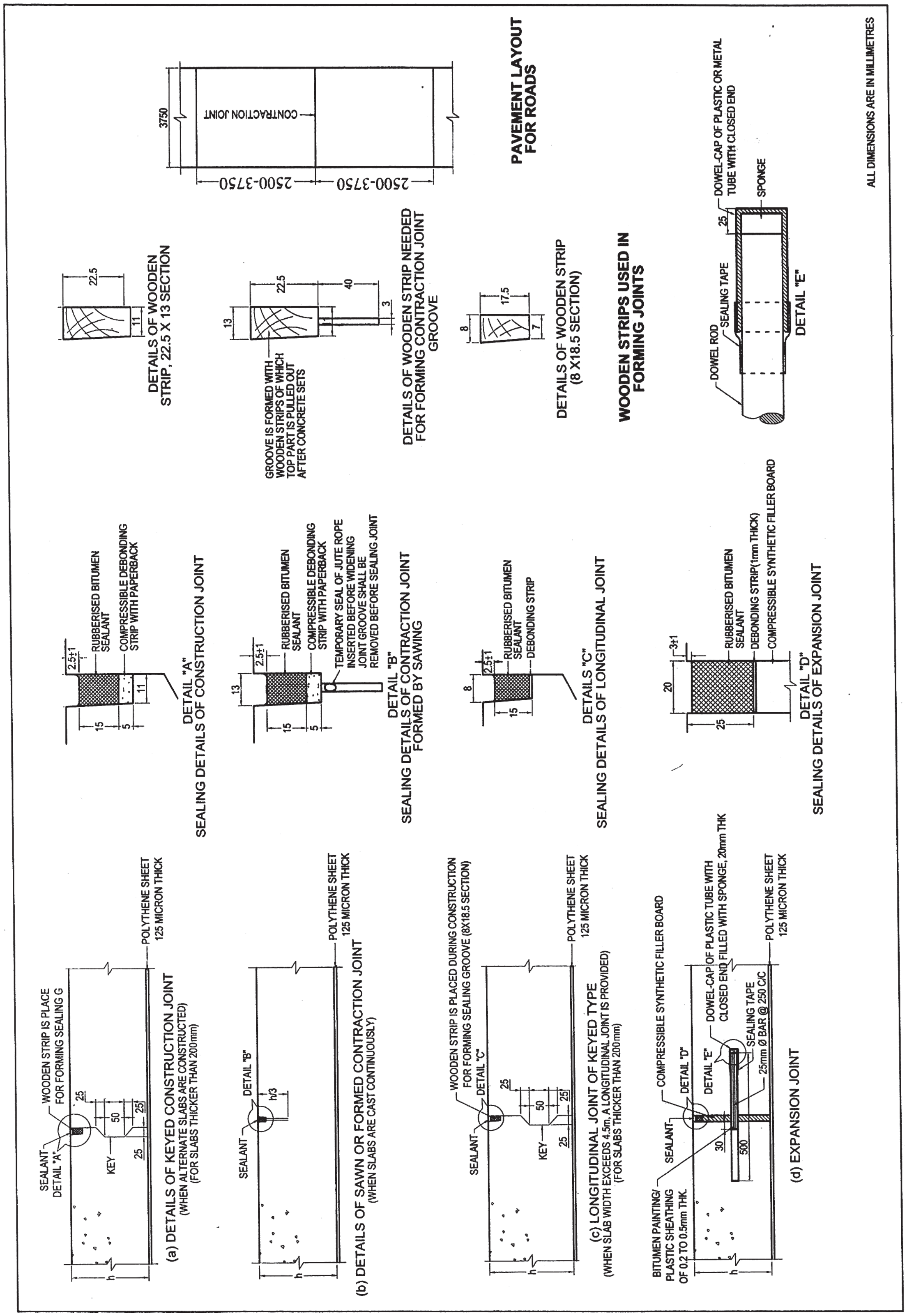
Since rural roads have low traffic with small wheel loads, the slab thickness being 150 . 250 mm, the aggregate interlock at the sawn joints is itself adequate for load transfer and no dowel bars are necessary. The arrangement for sealing of sawn joints is given in Fig. 7.6(b). If slabs are cast in alternate panels, keyed joints can be formed as in Fig. 7.6(a). Day.s work should normally be terminated at a contraction joint.

At expansion joints, where the joints width may be 20mm, dowel bars are required as shown in Fig. 7.6 (c). Recommended dimensions of dowel bars are given in table. 7.6.

Table 7.6 Recommended Dimensions of Dowel Bars

Slab thickness (mm)	Dowel Bar Details		
	Dia (mm)	Length (mm)	Spacing (Centre to Centre) (mm)
Upto 200	25	500	250
250	25	500	300

Fig. 7.6 Details of joints in cement concrete pavement for rural roads



7.8. ILLUSTRATIVE DESIGN EXAMPLE

A cement concrete pavement is to be designed for a Rural Road in South Tamil Nadu having a traffic volume of 150 vehicles per day consisting vehicles like agricultural tractors/trailers, light goods vehicles, heavy trucks, buses, animal drawn vehicles, motorized two-wheels and cycles. Design the pavement. The soil has a soaked CBR value of 4.

Design

(1) Wheel load

The wheel load appropriate for the traffic conditions is 51 kN.

(2) k value

From Table 1, the k value corresponding to a CBR value of 4 is 35 N/mm2/mm.

Sub-base

Provide a 75mm thick WBM course.

Effective k Value

Since a sub-base is provided, the k value can be increased by 20%

Effective k value = $1.20 \times 35 \times 10^{-3} = 42 \times 10^{-3}$ N/ mm^2/ mm

Concrete Strength

Adopt a 28 day compressive strength of 30 MPa.

Flexural strength $f_f = cf\ 0.7\sqrt{f_c} = 3.834$

$\therefore$ 28 day Flexural strength = 3.834 MPa

90 day flexural strength = 1.20 x 3.834 MPa

= 4.6Mpa

Thickness

Try $a = \sqrt[4]{\frac{Eh^3}{12(1-\mu^2)k}}$ mm

Edge Load Stress

From Fig. 4, edge load stress for k = 42×10^{-3} N/mm^3, edge load stress is 4.5 MPa.

Temperature Stresses

From Table 7.4, the temperature differential for South Tamil Nadu for a slab thickness of 150 mm is 15 ºC.

Assuming a contraction joint spacing of 3.75 m and 3.75 m width, the radius of relative stiffness l, is as under:

L = 3750 mm

VI- 17

B = 3750 mm

l = radius of relative stiffness

E = 3 x 104 N/mm2
h = 150
= 0.15
k = 42×10-3 N/mm2/mm

Substituting the values in the above equation,

l = 673.3 mm

$$L/\circ = \frac{3750}{673.3} = 5.57$$

$$W/\circ = \frac{3750}{673.3} = 5.57$$

Both values are same.
For L/○= 5.57, Bradbury.s coefficient C = 0.834
Using chart at Fig. 7.1,

σt_e = 1.9 MPa

Total Stress

Total stress = Edge load stress + Temperature stress
= 4.5 + 1.9
= 6.4 MPa

This is greater than the allowable flexural strength of 4.60 MPa
So thickness of 150 mm assumed is inadequate.

Try a thickness of 200 mm.

Edge Load Stress

From Fig. 4, edge load stress, σœ = 2.75 MPa.

Temperature Stresses

From Table 3, the temperature differential for Tamil Nadu for a slab thickness of 200 mm is 16.4 ^{o}C.

l = radius of relative stiffness

$$= \sqrt[4]{\frac{Eh^3}{12(1-\mu^2)k}}$$

E = 3 x 104 N/mm2

h = 190

μ = 0.15

k = 42×10^{-3} N/mm^2/mm

Substituting the values in the above equation,

l = 835 mm

L/l = 3750/835 = 4.49

W/l = 3 750/835 = 4.49

Both values are same.

For L/○= 4.49, Bradbury.s coefficient C = 0.571

Using chart at Fig. 1,

Temperature Stress, σt_e = 1.7 MPa

Total Stress = 2.75 + 1.7 = 4.45 MPa

The total stress is less than 4.6 MPa and hence the assumed thickness of 200 mm is OK.

Corner Stress

From Fig. 5, corner load stress for wheel load 51 kN,

k = 42×10^{-3} N/mm2/mm

Slab thickness = 200 mm

Corner Stress σl_c= 3.1 MPa

The corner stress is less than 4.6 MPa and hence the thickness of 200 mm assumed is safe.

7.9. ROLLER COMPACTED CONCRETE PAVEMENT (RCCP)

Mix design for RCCP is totally different from the design of mix for a conventional cement concrete pavement as the Abrahm.s water/ cement ratio law does not hold good. Roller Compacted Concrete is a no-slump concrete.

The mix shall be proportioned by weight of all ingredients such that the desired target mean strength is achieved. The mix design shall be based on the flexural strength of concrete. The moisture content shall be selected so that mix is dry enough to support the weight of a vibratory roller, and yet wet enough to permit adequate distribution of paste throughout the mass during mixing, laying and compaction operations. The water content may be in range of 4 to 7 per cent by weight of dry materials including cement. Trial mixes may be made with water contents in the range of 5-7 per cent and shall be determined by trial mixes with water content changing at 0.5 per cent intervals. The optimum moisture content which gives the maximum density shall be established. The exact moisture content requirement in the mix shall be established after making field trial construction.

Using the moisture content so established, a set of six beams and cubes shall be prepared for testing on the 7th and 28th days. If the flexural strength achieved is lower than the desired strength, the trials should be repeated after increasing the cement/ fly-ash content till the desired strength is achieved.

7.10. INTERLOCKING CONCRETE BLOCK PAVEMENTS

7.10.1. INTRODUCTION

Interlocking concrete block pavements consists of a surface layer of brick . sized concrete blocks paved on a thin, compacted bedding sand layer of specified grading, which is spread over a properly profiled base course and is bounded by edge restrains. The joined are sealed with joint filling sand, also of specified grading. The block layer is embedded into bedding sand by vibratory compaction. In concrete block pavements rectangular blocks are used which are non interlocking when paved, while in interlocking concrete pavement blocks with curved vertical spaces are used, which have enhanced interlocking effect when paved.

Paving quality concrete is used for production of precast blocks and edge restrains. Ordinary Portland cement/Portland Pozzolana cement / Portland slag cement meeting the relevant specifications are used as binder. Good quality natural course

and fine aggregates meeting the specifications requirements as per IS: 383 . 1970 should be used in concrete. Industrial waste products like fly ash, slag etc meeting relevant specifications can also be used as additives. Potable water should be used for making concrete use. Concrete blocks are normally produced using properly designed cement concrete mix. However, the blocks so produced should have equivalent as per design requirements.

7.10.2. ADVANTAGES

i. The paving system offers the advantages of concrete materials and flexible asphalt pavement.

ii. As high strength concrete, the units have high resistance to freeze-thaw cycles and de-icing salts, high abrasion and skid resistance, no damage from petroleum products as well as from concentrated point loads or high temperatures.

iii. Once installed there is no waiting time for curing. The pavement is immediately ready for traffic.

iv. Stress cracking and degradation of surface is minimized because the numerous joints, or intentional “cracks”, acts as a means for load transfer.

v. Like flexible asphalt pavement, an aggregate base accommodates minor settlement without surface cracking. An aggregate base facilitates fast construction, as well as access to underground utilities.

vi. Mechanical installation of concrete pavers can further shorter construction time. Pavement reinstatement is enhanced by reusable paving units, there by reducing wasting materials.

7.10.3. PRINCIPLES OF INTERLOCK

Interlock is critical to the structural performance of interlocking concrete pavement. When considering design and construction, three types of interlock must be achieved vertical, rotational and horizontal interlock. Vertical interlock is achieved by the shear transfer of loads to surrounding units through sand in the joints. Rotations interlock is maintained by the pavers being of sufficient thickness, placed closely together, and restrained by a curb from lateral forces of vehicle tires. Rotations interlock can be further enhanced if there is a slight crown to the pavement cross section.

Decides facilitating drainage, the crown enables the units to tightens through loads and minor settlement across the entire pavement, there by increasing structural capacity. Horizontal interlocking is primarily achieved through the use of laying patterns that disperse forces from braking, turning, and accelerating vehicles. The most effective laying patterns for maintaining interlock are herringbone patterns.

7.10.4. DESIGN CONSIDERATIONS

The evaluation of four factors and their inter-active effects will determine the final pavement thickness and material. These include environment, traffic, sub-grade soil strength, and pavement materials. The design engineer selects values representing attributes of these factors. There can be very approximate correlations and qualitative assumptions. Each factor, however, can be measured accurately with detailed engineering studies and extensive laboratory testing. As more detailed information is obtained about each factor, reliability of the design will increase. Fig 7 shows some of the interlocking concrete blocks shapes.

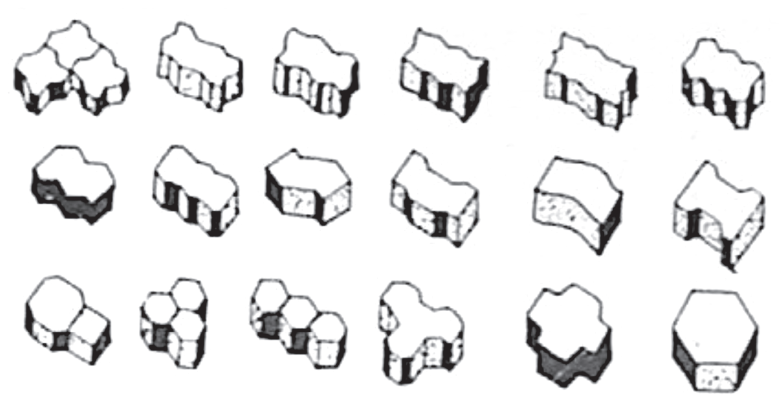


Fig.7. Shapes of concrete blocks

7.11.METHODOLOGY OF CEMENT CONCRETE PAVEMENT

Methodology:

1. Sub-grade is prepared as per procedure mentioned in chapter – 4 & 5.
2. The concrete pavement for rural roads shall be laid on a properly compacted sub-base which shall be on a subgrade of selected coarse grained soil of 15 cm

thickness. The sub base may be composed of granular material or stabilized soil or semi rigid material as listed below.

3. **(a) Granular material**

- Water Bound Macadam (WBM)
- Well graded granular materials, like, natural gravel, crushed slag, crushed concrete, brick metal, laterite, kankar, etc. confirming to IRC 63-1976.
- Well-graded soil-aggregate mixtures conforming to IRC 63-1976.

(b) Stabilised soil

- Local soil or moorum stabilized with lime or lime-fly ash or cement, as appropriate to give a minimum soaked CBR of 20 after 3-days of curing and 4-days of soaking. For guidance as regards design of mixes with cement or lime, a reference may be made to IRC:51 and IRC:50 respectively.

The thickness of sub-base shall be minimum 75 mm, where the pavement is designed for low traffic (i.e.wheel load - 30 KN) and the material is of any of the types listed in (a) and (b) above. A thickness of 150 mm may be adopted where the pavement is designed for heavy traffic (i.e.wheel load - 51 KN).

The sub-base shall be constructed in accordance with the respective specification and the surface finished to the required lines, levels and cross-section.

4. Form work for cement concrete slab shall be over the base course it shall be set to true level and securely fixed in position to prevent any subsequent disturbance during compaction.

5. Mixing of concrete shall be done in a power driven mixer of approved type that will ensure a uniform distribution of materials. The mixer with hopper attachment should only be used.

6. Concrete shall be placed on the prepared base between form work in such a manner as to avoid segregation and uneven compaction. Concrete shall be deposited within 20 minutes and compacted within 60 minutes in summer

and 75 minutes in winter. Concreting shall not be done when the atmospheric temperature is below 5^0 C and above 35^0 C.

7. Concrete shall be compacted fully using vibrating screed and internal vibrator. Water in fresh concrete should not be in excess of the stipulated quantity, otherwise concrete is like to crack within very short period after drying. After compacting and finishing with screed a float and then a broomer is used to finally finish the top surface with required texture to avoid skidding. Any depressions or high spot showing deviation from the true surface shall be immediately rectified. High spots shall be cut down and refinished.

8. Contraction and expansion joints shall be provided as per the guidelines mentioned in IRC : 15 or IRC : 58. All materials required for the joints. viz, tie bars at longitudinal joints, dowel bars at expansion joints, expansion joint filler boards and joint sealing compounds shall be checked for specifications requirements as per IS : 1834 and IRC.

9. Curing shall commence soon after the finished pavement surface can taken the wet burlap, cotton or jute mats normally apply for initial curing, without leaving any marks thereron (ISR:11). The mates shall extend beyond the pavement edges at least by 0.5 m and be constantly wetted. Initial curing shall be for 24 hours or till the concrete is hard enough to permit labour operations without damages. Up to 24 hours no water other than mixing water, should be added to the surface of concrete except just wet burlaps. Final curing, after removal of the mats, etc. shall be carried out by wet ponding earth, ponding of water or other means specified. Where water is scarce or pavement is on steep gradient, impervious membranes curing shall be adopted.

10. **Joint filler:** Bitumen impregnated fuller board or synthetic joint filler board may be used for expansion joints as per drawing and material should comply the requirement of IS:1838. The board should extend little more beyond edge of pavement and side form. The holes shall be accurately bored or punched out to have sliding fit on the dowel bars.

11. **Joint Sealing Compound:** This shall be hot poured sealing compound of reputed make having desired flexibility, resistance to age, hardening and durability conforming to IS:1834.

CULVERTS AND BRIDGES

8. CULVERTS AND BRIDGES

8.1. INTRODUCTION:

In order to adopt uniform standards and to assist the field engineers, various technical details regarding Culverts and bridges are explained in this chapter.

8.1.1.Glossary of technical terms:

Culvert is a cross drainage structure having a total length of 6m or less between the interface of dirt wall or extreme vent-way boundaries.

Minor bridge is a Bridge having a total length upto 60m.

Small bridge on rural road could be generally taken as a bridge with a length between 6m and 30m and where the vent of the individual span is not more than 10 m.

High level Bridge is a bridge having its Bottom of Deck(BOD) fixed above the Maximum Flood Level(MFL) taking into account the vertical clearance.

Square bridge is a bridge having its alignment crossing the river at the right angle to the direction of flow.

Skew bridge is provided where the alignment crosses the river with an angle of more than 90^0 or less than 90^0 with reference to the direction of flow. The skew angle is the angle measured between the direction of flow and perpendicular to the alignment of the road.

Foot bridge is a bridge exclusively used for carrying pedestrians, cycles and animals.

Submersible bridge is a bridge which gets submerged during high floods in monsoon for some duration but is available for trafiic otherwise.

Causeway is a paved submersible structure with or without openings (vents) which allows flood to pass through and/or over it.

Ford is an unpaved shallow portion in a river or stream bed which can be used as a crossing during dry weather/normal flow.

Channel means a natural or artificial water course.

Sill Level - generally, the bed level at site is fixed as sill level.

Clearance is the shortest distance between the boundaries at a specified position of a bridge structure.

Vertical clearance is usually the height from the design highest flood level with afflux of the channel to the lowest point of the bridge superstructure at the position along the bridge where clearance is being denoted.

Freeboard at any point is the difference between the highest flood level after allowing for afflux, if any, and the formation level of road embankment on the approaches or top level of the Deck slab.

Highest flood level (HFL) is the level of the highest flood ever recorded or the calculated level for the design discharge, whichever is higher.

Ordinary flood level (OFL) is the level of flood expected to occur every year. It can be determined by averaging the highest flood levels of seven consectutive years.

Design Flood Level (DFL) is the highest flood level for which the structure must be designed. It corresponds to the level of highest flood of 50 years or 100 years return period (whichever is chosen for design) or the highest known flood level if the same happens to be higher.

Low water level (LWL) is the level of the water surface attained generally in the dry season. It can also be determined by averaging the low water levels recorded in seven consecutive years.

Protected Bed level (PBL) is the level at which the bed surface is protected against erosion due to flow of water.

The length of a bridge structure will be taken as the overall length measured along the centre line of the bridge between inner faces of dirtwalls.

Clear span is the clear distance between the adjacent piers or the clear distance between the face of the abutment and the adjacent pier.

Linear Water way(LWW) of a bridge is the total width of the waterway of the bridge at MFL after deducting width of the obstruction.

Effective linear waterway is the total width of the waterway of the bridge at HFL minus the effective width of obstruction.

Safety kerb is a roadway kerb for occasional use of pedestrian traffic.

The width of carriageway is the minimum clear width measured at right angles to the longitudinal centre line of the bridge between the inside faces of roadway kerbs or wheel guards.

Dirt Wall is the wall over the abutment to prevent the earth from the approach road spilling on the bearings

Bed Block is a concrete block resting over the top of the piers/abutments, provided to evenly distribute the dead and live loads on the pier/abutments.

Wing Wall is the wall adjacent to abutment with its top up to road level near abutment and sloping down up to ground level or a little above at the other end.

Return Wall is the wall adjacent to abutment generally parallel to road or flared up to increase width and raised up to the top of road.

Shallow Foundation: The foundation having shallow depth is generally known as shallow foundation. If the depth is less than the width of foundation, then the foundation is generally called Shallow foundation (e.g open foundation, raft foundation)

Deep Foundation: If the depth of foundation is greater than the width of foundation, it is generally called as deep foundation (e.g. well foundation, pile foundation)

8.1.2. GENERAL GUIDELINES

Certain general guidelines as detailed below are given to aid and facilitate appropriate use of specifications given in this Section.

(i) These Specificatons provide for foundations placed in open excavations (open type of foundations) only as other types of foundations like raft, wells or piles are not aniticipated in cross - drainage works and minor bridges in rural road works. If such types of foundations are specified in drawings, the work shall be carried out in accordance with relevant clauses of "Ministry of Road Transport & Highways-Specifications for Road and Bridge Works".

(ii) The sections of piers, abutments, wing walls/return walls shall conform to Plates 7.02 to 7.05 of IRC:SP:20 "Rural Roads Manual"

(iii) Design and details of RCC solid slabs for spans 1.5m to 15m having overall width of 6.0 m, 6.4 m and 7.5 m shall conform to Plates 7.1 to 7.16 of IRC:SP:20 "Rural Roads Manual

(iv) Design and Details of RCC box cell bridges shall conform to Plates Nos. 7.18 & 7.19 of IRC:SP:20 "Rural Roads Manual"

(v) Unless otherwise specified in the drawings or directed by the Engineer, concrete Grade of M25 and HYSD reinforcement conforming to IS:1789 shall be used for superstructure.

(vi) For minor bridges having individual span upto 10m and R.C.C. Slab Culverts (length upto 6m), filler joints comprising 25 mm thick premolded filler or burried joints shall be provided.

(vii) Elastomeric slab seal or compression seal expansion joints shall be provided for minor bridges having multiple spans with individual span more than 10 m.

(viii) Concrete wearing coat over minor bridges and culverts shall only be provided if specified in the drawing. The grade of cement concrete wearing coat shall be M30 (Design Mix Only)

(ix) Plain cement concrete structures shall be provided with minimum skin reinforcement of 2.5 kg/m2 on all exposed surfaces in both horizonal and vertical directions, The spacing of skin reinforcing bars in each direction shall not be more tha 200 mm c/c.

8.2. OVERALL WIDTH OF CD WORKS:

- The overall width of the culvert should be equal to the formation width of the road. In rural roads, the road way width is 7.50m in plain and rolling terrain.
- However, from cost and low traffic point of view, 6.0m formation (road way width) can also be adopted for such roads, which connect only a small habitation and where length of the road is minimal.

Table : 8.1. Overall Width of CD Works (IRC SP : 20 - 2002, Page No. 127)

Type of CD works	7.50m road way width		6.0m road way width	
	Overall width, (in m)	Carriage way, (in m)	Overall width, (in m)	Carriage way, (in m)
Culverts	7.50m	6.60m	6.00m	5.50m
Small and Minor Bridges	6.40m	5.50m	6.00m	5.50m
Submersible Bridges	7.50m	6.60m	6.00m	5.50m

- The carriage way width of CD structure is generally the overall width minus the kerbs and railings which should normally allow passage of two trains of IRC class A loading.
- In case of roads with low traffic intensity, and in hilly terrain where overall width is 6m, it is adequate to provide 0.25m wide kerb raised from slab. Clear width of carriage in these cases will be 5.50m.
- For pipe culverts on rural roads it would be desirable to provide 3 pipes of 2.50m length each, to avoid cutting of pipes. This will mean that clear width on these culverts would be 7.50m width minus the width of guard stone or parapet wall.
- For buried pipe culverts with embankment of more than 1.0m above the pipe, length of pipe should be suitably increased.

8.3. SITING OF CULVERTS ON GRADIENTS:

- The cross drainage works should generally be sited on the straight alignment of a road.
- If a nalla crosses the road other than at right angle either a skew culvert should be provided or, if economical, the nalla should be suitably drained.
- If the road at the culvert is in gradient, the same gradient of road may be provided for deck slab of the culvert.
- If the culvert is situated at change of gradient (hump) the profile of the vertical curve should be given in the wearing coat on the culvert. In such cases the levels of two abutment caps on either side may not be the same.

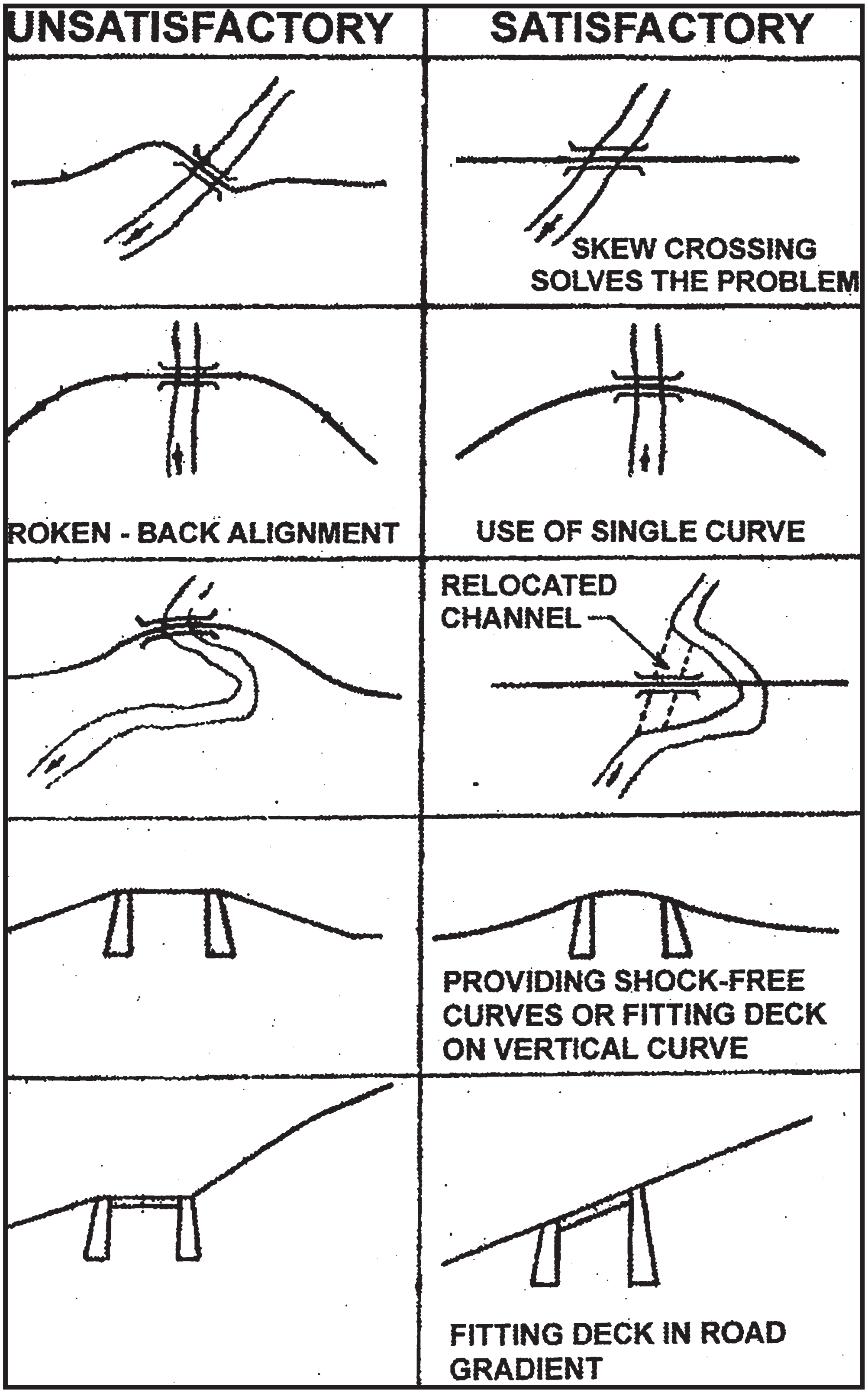


Fig : 8.1. Satisfactory and unsatisfactory location, alignment and profile for culverts

8.4. KERB AND PARAPET WALL:

- Parapet walls of culverts generally consists of either Random Rubble (RR) or Coarse Rubble (CR) stone masonry in cement mortar 1:5 or RCC railings of 0.8m height above kerb.
- Where overall roadway is 7.5m or 6.4m, the combined width of kerb and parapet is 450mm as per standards. However for 6.0m wide culverts or bridges, 250mm wide RCC kerb, 300mm above road level should be provided.
- If considered necessary, either pipe railing or guard stones of 200x200mm section projecting 300mm above kerb and spaced at 1200mm c/c may be fixed
- In case of small bridges with 7.5m and 6.4m overall width, parapet may be of Plain Cement Concrete (PCC) railing or brick masonry or guard stones.
- At the end of parapets and returns, 400x400x600mm RCC blocks are provided at four corners at the end of returns. Numbering of culverts and direction of flow can be marked on these pillars.

8.5. DESIGN LOADING:

- Culvert and bridges of 6m, 6.40 m, 7.50m overall width on rural roads are normally designed for two lanes of IRC class A loading with impact.
- In exceptional cases single lane bridges are provided. They may be designed for a single lane of IRC class A loading with impact.

8.5.1. CLASSES OF LOADING :

Road bridges and culverts shall be divided into classes according to the loadings they are designed to carry.

I.R.C. Class AA Loading: This loading is to be adopted within certain municipal limits, in certain existing or contemplated industrial areas, in other specified areas, and along certian specified highways, Bridges designed for Class AA Loading should be checked for Class A Loading also, as under certain conditions, heavier stresses may be obtained under Class A Loadings.

Note: "Where Class 70-R is specified, it shall be used in place of IRC Class AA loading".

I.R.C. Class A Loading: This loading is to be normally adopted on all roads on which permanent bridges and culverts are constructed.

I.R.C. Class B Loading: This loading is to be normally adopted for temporary structures and for bridges in specifid areas. Structures with timber spans are to be regarded as temporary structures for the purpose of this Clause.

8.6. Grade of Concrete

In the past, M10 and M15 grades of cement concrete were extensively used in CD works. As per IRC: 21, the minimum grade of structural concrete is M20 (design mix). Where the quantum of concrete work is small as in CD works of rural roads, it is suggested to use nominal mix based on volumetric proportion of cement, sand and aggregate with a low water cement ratio upto0.45 (Maximum). The minimum quantity of cement shall be 310 kg/m3. Super plasticizers @300 ml per 50 kg of cement could be used to improve workability. With the use of plasticisers, the w/c ratio can be brought down to 0.4. Needle and form vibrators should be used for compaction of concrete and power driven concrete mixer used to produce concrete for all culverts.

Structural Cement concrete is of two grades, namely "Design Mix Concrete" and "Nominal Mix Concrete".

Table :8.2. Minimum Cement Content and Maximum Water-Cement Ratio

Structural Member	Minimum cement content (kg/cu.m.)		Maximum water-cement ratio	
	Conditions of Exposure		Conditions of Exposure	
	Normal	Severe	Normal	Severe
(a) Plain Cement Concrete members (PCC members)	250	310	0.50	0.45
(b) Reinforced Cement Concrete members (RCC members)	310	400	0.45	0.40

Table: 8.3. Minimum Strength of Concrete

Structural Mamber	Conditions of Exposure	
	Normal	Severe
(a) Plain Cement Concrete members (PCC members)	M15	M20
(b) Reinforced Cement Concrete members (RCC members)	M20	M25

Note: *(i)* *The minimum cement content is based on 20 mm aggregate (nominal maximum size). For 40 mm and larger size aggregates, it may be reduced suitably but the reduction shall not be more than 10 per cent or 30 kg per cu.m whichever is lower. For 12.5 or 10 mm size aggregates, it shall be adjusted suitably. But the increment shall not be less than 10 per cent or 40 kg per cu.m whichever is higher.*

(ii) *For underwater concreting and hand mixed concrete, the cement shall be increased by 10 per cent.*

(iii) *Severe conditions of exposure shall mean alternate wetting and drying due to sea spray, coastal environments, direct contact with liquid/solid aggressive chemicals, corrosive fumes, high rainfall, alternate wetting and drying combined with freezing, and buried in soil having corrosive effect.*

Table: 8.4. Grade of Concrete

Grade	Nominal mix	Usage
M10	1:3:6	Lean concrete as leveling course, Foundation concrete below abutments and piers
M15	1:2 ½ :5	Concrete blocks, PCC Pier, for Abutment, wing/Return Wall, Foundation for RCC works
M20	1:2:4	RCC pier, Abutment caps, Raft foundations, Dirt walls
M25	1:1 ½ :3	RCC superstructure
M30	1:1:2	Wearing Coat

Note: *(i) Mix proportions are by weight and 43 grade cement is used in nominal mix.*

(ii) Since strength of a mix depends on the size and quality of aggregates actually used, the proportions shall be verified by testing of cubes before adoption of proportions at site.

Table: 8.5. Proportions for nominal mix concrete

Grade of concrete	Total quantity (kg) of dry aggregate by mass per 50 kg of cement to be taken as the sum of individual masses of fine and coarse aggregates (kg)	Proportion of fine aggregate to coarse aggregate (by mass)	Quantity of water per 50 kg of cement (Max. Litres)
M10	480	Generally, 1:2 subject to an upper limit of 1:1 1/2 and a lower limit of 1:2 1/2	34
M15	330		25
M20	250		25
M25	180		22

Note: *(i) The Proportions of fine coarse aggregate shall be adjusted from upper limit to lower progressively as the grading of fine aggregates becomes finer and the maixmum size of coarse aggregate becomes larger. Graded coarse aggregates shall be used.*

(ii) The cement content of the mix shall be proportinately increased in case extra water is added from placement and compaction consideration to ensure that water-cement ratio as speified is not exceeded.

(iii) Based on the density, Volumetric proportioning of materials by using measurement box should be done at site when concrete mixer fitted with weigh batcher is not used

8.7. WEARING COAT:

- When the road is with bituminous surface, it is desirable to provide 20mm thick premix carpet (PMC) with a 5mm thick seal coat as wearing coat on culvert.

- If the rural road is not Black topped, concrete wearing coat can be adopted for CD works.

- For submersible structure like Arch/vented causeway, M30 grade cement concrete wearing coat of 75mm thickness must be provided.

8. NAME PLATES NUMBERING OF CULVERTS:

- Two name plates or plastered surfaces should be provided on the road side faces of 0.60m high guard stone.
- Number of culverts, description of type, the direction of flow and their chainages should be inscribed on the left hand side end faces of returns in both directions.
- In case of pipe culverts, 2 guard pillars of 400x400x600mm should be provided on left-hand side in either direction for recording the number of the culvert.
- The culverts are designated in the form of a fraction, the numerator denoting the number of kilometer and the denominator to indicate the kilometer wise serial number of the structure. For example 11/3 indicates the 3rd culvert between 10th and 11th km stone.
- The size of the letter shall not be less than 100mm high and shall conform to IRC 30.

8.9. DESIGN OF CULVERTS (HYDRAULIC ASPECTS):

- The topography of the land across the country varies widely and conditions may be dissimilar even within the same state depending on the annual rain fall and nature of terrain. The hill streams are flashy in nature, which need tall substructure to span them. The nature of the stream in plain and rolling terrains are usually wide and have longer superstructure with relatively shorter substructure. The man made drains both for irrigation and industrial use could be low cost structures such as pipe culverts.

8.9.1. Hydraulic calculation for Culvert

The design discharge was calculated by the rational method considering peak runoff from catchment using the formula,

Discharge, $Q = 0.028\ Pf\ A\ I_C$

Where Q = Maximum run - off in m^3/s, P = Coefficient of run off for the catchments characteristics, A = Catchments Area in Hectares, I_C = Critical intensity of rainfall in cm per hour and f = fraction depends on the area "a" and the relation is represented by the curve in Fig: 8.2.

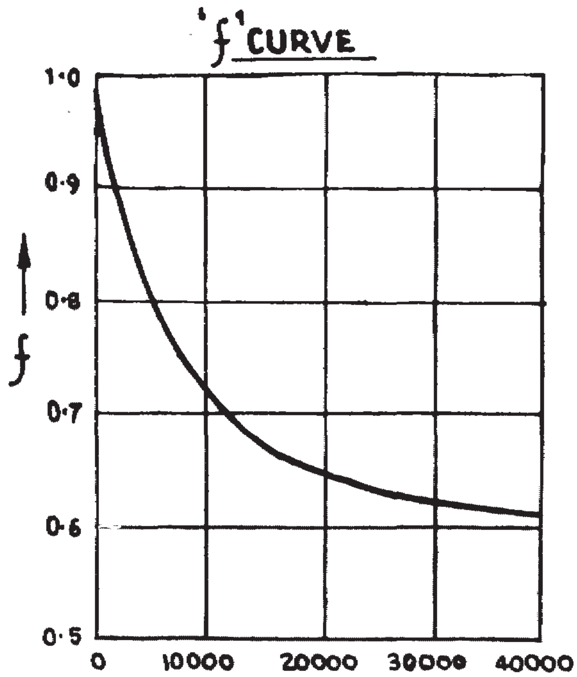


Fig: 8.2. Catchment area in hectares

8.9.2. Coefficient of run off for the catchments characteristics (P)

The principal factors governing P are (i) porosity of the soil, (ii) area, shape and size of the catchment, (iii) vegetation cover, (iv) surface storage, viz, existence of lakes and marshes, (v) initial state of wetness of the soil. Catchments vary so much with regard to these characteristics that it is evidently impossible to do more than generalise on the values of P. Judgment and experience must be used in fixing P. Also see Table: 8.6. for guidance.

TABLE : 8.6 MAXIMUM VALUE OF PIN THE FORMULA $Q = 0.028\ PAI_C$

Steep, bare rock, Also city pavements	0.90
Rock, steep but wooded	0.80
Plateaus, lightly covered	0.70
Clayey soils, stiff and bare	0.60
Clayey soils, lightly covered	0.50
Loam, lightly cultivated or covered	0.40
Loam, largely cultivated	0.30
Sandy soil, light growth	0.20
Sandy soil, covered, heavy brush	0.10

8.9.3. Critical intensity of rainfall in cm per hour (I_C) :

The critical intensity for a catchment is that maximum intensity which can occur in a time interval equal to the concentration time t_C of the catchment during the severest storm (in the region) of a given frequency I_C. Since each catchment has its own t_C it will have its own I_C

$$I_C = I_O (2/ (t_C + 1))$$

8.9.4. Time of concentration (t_C) :

The time taken by the run-off from the farthest point on the periphery of the catchment (called the critical point) to reach the site of the culvert is called the "concentration time".

The concentration time in hours, $t_C = (0.87 \times L^3 / H)^{0.385}$

L = the distance from the critical point to the culvert in km.

H = the fall in level from the critical point to the culvert in metres.

L and H can be found from the survey plans of the catchment area

8.9.5. One-hour rainfall (I_O) :

The peak run-off resulting from the severest storm (in the region) that occurs once in 50 years or any other specified period. The total precipitation of that storm be F cm and duration T hours. Consider a time interval of one hour some where within the duration of the storm. The precipitation in that hour could be one-hour rainfall I_O cm.

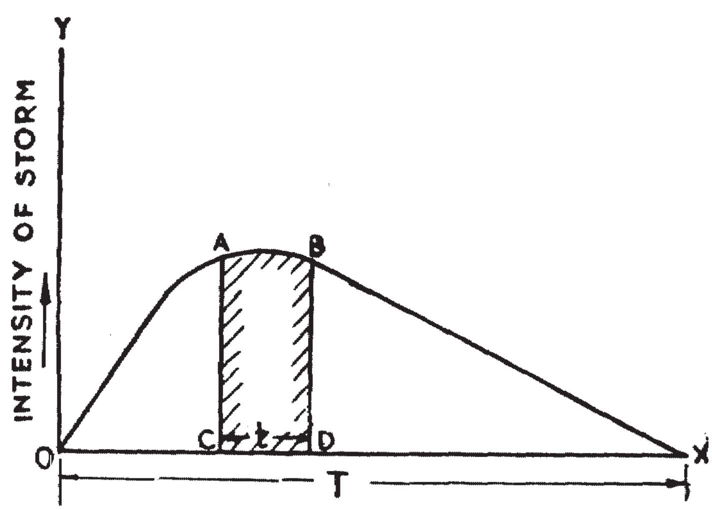


Fig: 8.3. Duration of Storm

The above Fig.8.3. represents the severest storm experienced in a region. If 't' represents one hour, then the shaded area ABCD will represent I_0.

It is convenient and common that the storm potential of a region for a given period of years should be characterised by specifying the "one hour rainfall" I_0 of the region for the purpose of designing the waterways of culvert in that region.

I_0 has to be determined from the F and T of the severest storm. That storm may not necessarily be the most prolonged storm. The correct procedure for finding I_0 is to take a number of really heavy and prolonged storms and work out I_0 from the F and T of each of them. The maximum of the values of I_0 thus found should be accepted as "the one hour rainfall" of the region for designing culverts.

The I_0 of a region does not have to be found for each design problem. It is a characteristic of the whole region and applies to a vast area subject to the same weather conditions. I_0 of a region should be found once for all and should be known to the local engineers.

One-hour rainfall in cm, $I_0 = F (1 + (1/T)) / 2$

F = rainfall in cm dropped by the severest storm in T hours.

8.9.6 WATER WAY AREA:

The water way of culvert is given by $A = Q/10.90$

Where Q = Catchments area in hectares

A = Water way in sqm

This formula is generally suitable for culverts with catchments upto 100 hectares and for catchment area of more than 100 hectares actual discharge of the stream to be determined by a suitable method.

8.9.7 LINEAR WATER WAY :

It is generally found that the linear water way for catchment area of 1 square km will be between 4 and 6m.

Statistical data shows that the relationship between the linear water way and the catchments area is given by the following empirical formula.

$L_w = k \times \text{sqrt}(Q)$

L_w= Linear waterway in m

Q = Catchments area in sq km and K varies from 4 to 6.

(This formula is not suitable for culverts with a catchment area of less than 1 sq km.)

On the basis of waterway area for catchment area of 1.25 Sq Km (125 Hectares) the waterway works out to be 6 m for a depth of flow of 2m, as follows:

A = 125/10.9 = 11.456 Sq m

L_w= 11.46/2 = 6.0 m

Thus for the catchment area of less than 1.25 sq km (125 hectares), a culvert is required and for a catchments area of more than 1.25 sq km a minor bridge is to be provided. If the depth of water is more say 3.0 m, a culvert of 6m water way can be provided upto a catchment area of 2 Sq km, i.e, 200 hectares. These Data are meant for guidance.

8.9.8. HYDRAULIC DATA:

The following data need to be collected for the design of a culvert

1. Catchments area of the stream in hectares
2. Cross-section of the stream at proposed crossing along with L-section of road upto 200m on either side of the culvert
3. L-section of nalla (for catchments area of more than 125 hectares) about 200m upstream and 200m down-stream to ascertain if straightening of the stream is necessary to fix the location of the culvert.
4. High Flood Level (HFL) / Maximum Flood Level (MFL)
5. Road Top Level (RTL)

In case of long bridges, the road top level is fixed on the basis of HFL after providing prescribed vertical clearance and calculated afflux.

In case of culvert, the RTL should not be fixed on the basis of HFL and vertical clearance alone. The gradient of road for 200m on either side should be examined and the road top level (RTL) should be fixed in such a way that RTL is not less than the

minimum requirement on the basis of HFL.

When the mean velocity of flow is more than 2.6m/sec, protection of entry and exit is desirable. Otherwise stone pitching of bed would be adequate. As per IRC-5 the vertical clearance for CD works varies from 150mm to 600mm as indicated in Table: 8.7

8.9.9 ROAD TOP LEVEL:

Most of the work of construction of culvert will be generally on new roads. Some works may, however, be on the existing roads. Culvert should be constructed simultaneously when the earth work of the road is in progress, whereby the geometric of road can be properly provided.

In many cases culverts are taken up after providing the road crust. This has two disadvantages:

1. Practically every culvert becomes a hump on the road and geometrics of the road are affected.

2. Duplication of work and consolidation of approaches causes extra cost.

The road top level at culvert should be fixed in advance.

8.9.10. MINIMUM SPAN AND CLEARANCE:

From the consideration of maintenance of culverts, it is preferable that the clear waterway of slab culvert is a minimum of 1.5m and diameter of pipe in case of pipe culvert is 1000mm (900 mm internal dia).

Culverts of small span or diameter get chocked due to silt. It is not possible to enter the pipe and carry out inspection and repairs in slab or pipe culverts where the width or diameter is less than the ones given above.

Irrigation pipes do not come under the purview of pipe culverts.

Minimum height of the soffit of the slab should be 1.5m above the lowest bed level from the consideration of inspection and maintenance. Table: 8.7. indicates clearance required for different spans.

Table: 8.7. (IRC SP : 20 - 2002, Page No. 130)

Span, (m)	Vertical clearance (mm)
1.0 and 1.5	150
2.0 and 2.5	300
3.0 and 4.0	450
5.0 and 6.0	600

(IRC SP 13 provides more detailed hydraulic calculations)

Table: 8.8. (IRC SP : 13 - 2004, Page No. 37)

Discharge in m^3/s	Minimum vertical clearance in mm
Upto 0.30	150
Above 0.3 and upto 3.0	450
Above 3 and upto 30	600
Above 30 and upto 300	900
Above 300 and upto 3000	1200
Above 3000	1500

(IRC SP 13 provides more detailed hydraulic calculations)

8.9.11. NUMBER OF CULVERTS PER KILOMETER:

It is observed that about 2-3 culverts are required per km length of road depending on the topography.

This may also vary from region to region and guidance can be taken from statistical data of existing roads.

When the ground generally slopes from one sides to another, the embankment intercepts natural flow of rainwater. In such cases, balancing culverts are provided at the rate of one per 500m length of road to avoid water logging. The balancing culvert could be a pipe culvert of minimum 900mm internal diameter.

8.10. TYPES OF CULVERT

The following types of culverts are generally provided:

a) RCC Pipe Culvert

b) RCC Slab on Masonry or Plain Concrete Abutment

c) RCC Box type Culvert

d) Arch Culvert

e) Cut Stone Slab Culvert

f) Stone Masonry Scupper

g) Vented Causeway

h) Submersible Bridge

The first three types of culverts are most popular across the country.

8.10.1 PIPE CULVERT

8.10.1.1 DIAMETER OF PIPE:

The Cost of Slab culvert is less if the foundation is within 2m from the bed level, otherwise, pipe culvert is chosen.

Although use of 450mm, 600mm diameter pipes in CD works was more popular in low to moderate rainfall regions, from inspection and maintenance point of view, a minimum of 900mm (internal) diameter is recommended.

However, taking into consideration the smaller length of barrel and low embankment heights, pipes of lesser dia, viz. 600mm or 750mm may also be used in exceptional situations.

RCC pipes of 300 mm and 450mm dia, used for purposes, such as, irrigation agriculture are to be considered as mere buried conduits and not as culverts.

The pipes for culverts of rural roads shall be of NP3 type, which conform to IS:458-1989 and can be chosen as per the following table.

Table: 8.9. Diameter of Pipe (IRC SP : 20 - 2002, Page No. 131)

Catchment Area (Hectares)	Diameter of Pipe (mm)
Up to 10	1000 single row
10 to 20	1200 single row
20 to 50	1000 or 1200 (2 to 3 rows)
50 to 60	1000 or 1200(4 rows)

The main advantage in pipe culverts is the speed of construction and good quality factory produced pipes. A pipe culvert can be constructed in 15 days.

8.10.1.2. HEIGHT OF CULVERT :

The minimum height of the formation level of the road from the bed level is required to be as per Table:8.10. in case of pipe culvert.

Table: 8.10. Minimum Height of Formation (IRC SP : 20 - 2002, Page No. 131)

Diameter (NP3 pipes) (in mm)	Height of Formation (in m)
For 1000 (900 mm internal dia)	1.75
For 1200	2.15

Minimum height in slab culvert will be 1.775 m which include height of abutment (1.5 m) thickness of RCC deck slabs (0.2 m) and wearing coat respectively (0.075 m). There is no difference in height in either slab or pipe culverts.

8.10.1.3. HEAD WALL:

The length of head wall is equal to four times the diameter of pipe for retaining the slope of earthen bank within 1 (vertical) to 1.5 (horizontal). Longer head walls are provided for wider streams as per site requirements.

The headwalls are raised up to top of the pipe and 0.5 m parapet wall is provided above it, in order to reduce the quantum of masonry wall and the cost.

Pipes are generally 2.5m or 3m long. It shall be ensured that the invert level of pipe is placed 150mm below the average bed level.

8.10.2. DESIGN ASPECTS:

The pipe shall conform to IS 458-1989 (Specification for Concrete pipes) and shall be laid as per IS 783-1985(laying of concrete pipes).

It may be ensured that the minimum height of fill above pipe including road crust shall be 1000mm.

8.10.2.1. EXCAVATION FOR PIPES

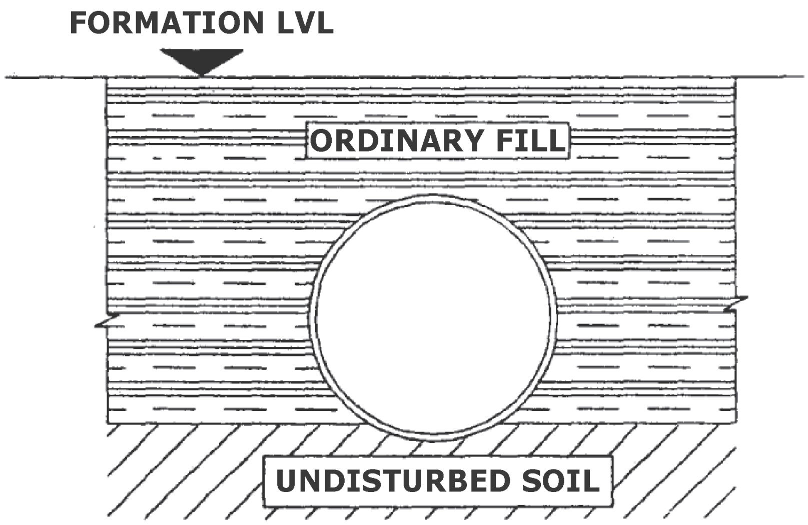
Lay the pipes in shallow excavation of natural ground or in open trenches cut in existing embankments taken down to required level.

For embankments of height of fill more than 3m, or three times the external dia of pipe above bed level, construct the embankment to the level above the top of the pipe (equal to external dia of pipe) and width not less than five times the dia of pipe. After Construction of embankment, a trench shall be excavated and the pipe shall be laid.

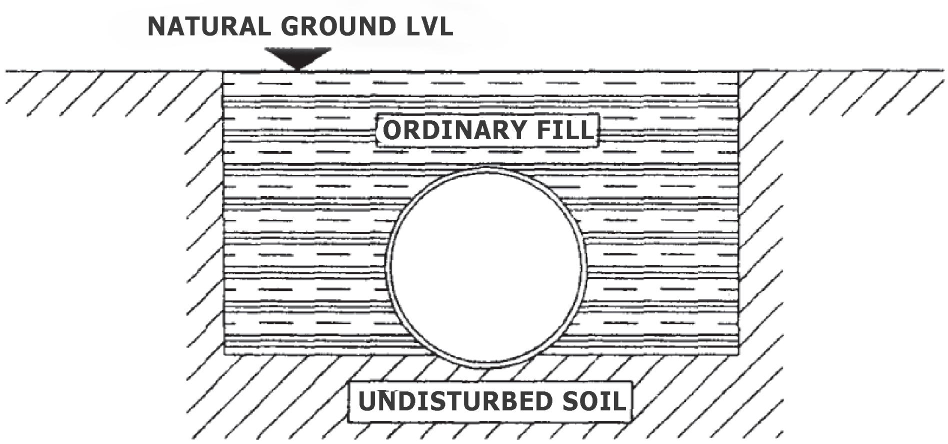
If spongy, soft or other unstable material is met with at the location of pipe culvert, remove the material to the required depth, width and length, and back fill with approved granular material properly shaped and compacted to the required level.

The width of trench in the embankment on either side of the pipe shall be one-fourth of the diameter of the pipe subject to minimum of 150 mm and shall not be more than one third diameter of the pipe. The side of the trench shall be as nearly vertical as possible.

Where rock or bouldery strata is met with, take down excavation to at least 200mm below the bottom level of pipe. Remove all loose material and fill the space with approved earth.



Positive Projection



Trench Condition

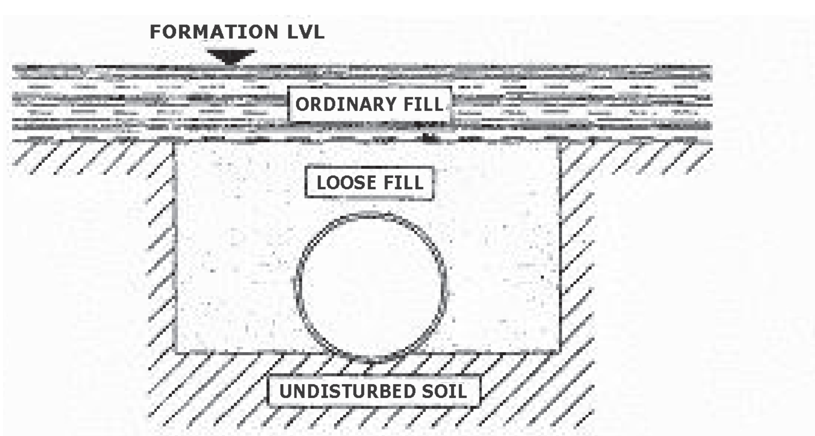


Fig: 8.4. Negative Projection
Different Conditions of Pipe Culverts in Foundations

8.10.2.2. BEDDING OF PIPES

Concrete cradle bedding (Type A) of thickness 250mm as per IRC SP : 13 -2004 below pipe should be provided for pipes of 1000 mm diameter and above and those with fills higher than 4 m.

First Class bedding (Type B) of thickness 250mm as per IRC SP : 13 -2004 below pipe is adopted for height of fill between 0.6 m and 4 m.

For expansive soils, provide a layer of sand / moorum or non - expansive material of minimum 450mm thickness under the bedding.

8.10.2.3 LAYING OF PIPES

When pipes are laid in two layers keep the centers of pipes in such a way that when joined shall form equilateral triangles.

Lay the pipes as specified in IS 783, for different conditions such as positive projecting condition, trench condition, etc.,

Lay the pipes on the prepared foundation, commencing from outlet and proceed towards the inlet. In case of pipes with bell mouth, keep the belled end facing the upstream. Keep the invert pipe minimum 150mm below average bed level. However if the invert level is more than 300mm, a catch pit of size 1500 x 1000mm upto ground level should be constructed.

Install the culvert with a camber, so that the settlement due to the load of the embankment will in time lower the culvert to the desired grade approximately.

Pre load the areas to induce major portion of settlement before the pipe is installed.

Provide a bedding surface of firm foundation of uniform density, throughout the length of the culvert with specified bedding material depending on dia of pipe and height of fill above pipe.

Lower the pipes in bed either by tripod pulley arrangement or by manual labour using chain pulley blocks in a manner to place them in proper position without damage.

The longitudinal slope of the pipe shall not be flatter than bed slope subject to minimum of in 1000 in plains. In case of culverts in hilly areas the longitudinal slope of the pipe shall be according to bed slope bu not steeper than 1 in 30 (normally, a slope of 1 in 100 shall be considered as good slope)

When two or more pipes are laid in adjacent to each other, place them separated by a distance equal to half the dia of the pipe subject to a minimum of 450mm.

8.10.2.4. JOINTING

Join the pipes either by collar joint or by flush joint. Place the collar such that its centre coincides with the joints and even annular space is left between the collar and the pipe.

Choose either internal flush joint or external flush joint. Fill the jointing space (13 mm wide) with CM 1:2 mix, which remain in position when forced with a trowel or rammer.

Fill the recess at the end of the pipe with jute braiding dipped in hot bitumen or suitable approved compound while jointing pipe lines.

Keep the width of collars 150 - 200 mm and caulking space between 13mm and 20mm according to dia of pipes.

8.10.2.5. BACK FILLING

The back fill of soil shall be clean from boulders, large roots, clay lumps retained on 75mm sieves, stones retained on 26.5mm sieve along with excessive amounts of sods and other vegetable matter.

Back fill trenches immediately after the pipes have been laid and jointing material has hardened. On top of pipe up to 300mm, thoroughly ram, tamp or vibrate the soil in layers not exceeding 150 mm. Thoroughly consolidate the materials under the haunches of pipes using light mechanical tamping equipment.

Carryout filling of the trench simultaneously on both sides of the pipe, such that unequal pressures do not occur.

When it is not possible to provide minimum specified cushion (i.e.,600mm) between the top of the pipe and the road level, pipe shall be encased in M10 concrete with cover of minimum 100 mm.

8.10.2.6. TOLERANCE

The following tolerances are permitted for concrete pipes as per IS 458

I. Overall length - ± 1% of standard length

II. Internal dia - ± 10mm

III. Barrel thickness

80 - 95mm	-	+ 5mm & - 2.5mm
Over 95mm	-	+ 7mm & - 3.5mm

8.10.3. RCC SLAB CULVERT AND MINOR BRIDGES

8.10.3.1. CATCHMENT AREA AND SPAN REQUIREMENT

For catchment area of more than 60 hectares, RCC Slab culvert are found to be economical and convenient.

The approximate relationship between the catchment area and the span is given in Table: 8.11. below.

Table: 8.11. Clear Span of Culverts (IRC SP : 20 - 2002, Page No. 132)

Catchment area (in hectares)	Clear span of culvert (in m)
Up to 15	1.5
16 to 25	2.0
26 to 50	3.0
51 to 75	4.0
76 to 100	5.0
101 to 125	6.0
126 to 200 (deep channels)	6.0

8.10.3.2 FOUNDATION

Take the minimum depth of foundation upto the stratum having specified bearing capacity but not less than 2m below the scour level where no bed protection is provided or 2m below the protected bed level.

In case of rock bed (or other material not erodible at tne calculated maximum velocity is encountered), ensure embedment of foundation into the rock below,the minimum depth being 600mm for hard rocks (crushing strength of 10 MPa) and 1500mm for all other cases (Soft / Weathered Rock) and not less than 2000 mm for erodible strata below the scour level or the protected bed level (as per IRC : SP : 82 - 2008).

Provide 300mm thick plain concrete M15 grade footing, unless otherwise specified on the drawings. Provide a minimum offset of 150mm for the base of substructure.

Set out plan dimension of the foundation at the bottom of the foundation trench and check with respect to original reference line and axis.

Before laying foundation concrete, clean the earth surface of all loose material and sprinkle water to wet. Provide side form work as per required dimension and heights.

Lay foundation concrete continuously to the required thickness upto the level of construction joint proposed.

Finish the concrete surface smooth with a trowel and ensure curing.

Carryout dewatering where necessary for laying of concrete so as to keep the water level below foundation level with adequate provisions / precautions.

Remove loose sand laid on foundation before commencement of back filling. Refill all spaces excavated and not occupied by permanent work with earth upto surface of surrounding ground, with sufficient allowance for settlement. All backfill shall be thorughly compacted. In case of excavation in rock, fill the Annular space around footing with M 15 grade concrete upto the top of the rock.

8.10.3.3. SUBSTRUCTURES (Abutments, Piers, Wing Walls and Return Walls)

Adopt either brick masonry or Course Rubble (CR) stone masonry or plain or reinforced concrete for piers, abutments and wing/return walls. In case, the height of the wing and return walls is less than 3 m, use Random Rubble (RR) masonry.

Before commencing the masonry / concrete work, scrub the foundation with wire brush and remove all loose material and wet the surface.

Make provision for weep holes in solid (non spill through) abutments and provide backfill.

In case of concrete piers, the numeber of horizontal construction joints shall be kept minimum. No vertical construction joint shall be provided.

The filling **(backfill)** behind solid abutments, wings and return walls should be selected with care. A general guide to the selection of soils is given below.

Table: 8.12. General guide to the selection of soils on the basis of Anticipated Embankment Performance (IRC 78 - 2000, Page No. 95)

Soil group according to IS: 1498 - 1970		Visual description	Max. Dry Density range in Kg / M^3	Optimum Moisture Content range in %	Anticipated embankment performance
Most Probable	Possible				
GW, GP, GM, SW, HP	-	Granular materials	1850 - 2280	7 - 15	Good to Excellent
SB, SM, GM, GC, SM, SC	-	Granular materials with soils	1760 - 2160	9-18	Fair to Excellent
SP	-	Sand	1760-1850	19-25	Fair - Good
ML, MH, DL	CL, SM, SB, SC	Sandy silts & Silts	1760 - 2080	10 - 20	Fair - Good

Backfilling should not be done with non-cohesive soil.

The filter material shall be well packed to a thickness of not less than 600 mm with smaller size towards the soil and bigger size towards the wall and provided over the entire surface behind abutments, wings or return walls to the full height.

Filter materials need not be provided in case of spill through type abutments.

Provide vertical expansion gaps of 20mm width between abutments and wing walls.

Provide coping for wing/return walls in plain concrete.

The top of the wing/return walls shall be carried above the top of embankment by atleast 100 mm to prevent any soil from being blown or washed away by rain over its top.

Normally the length of return should be 1.5 times the height of aboutment above lowest bed level. However, if the height of road top from the bed level at abutment is more than 4m, the length of returns should be suitably worked out.

In case of open foundation, wing and return walls should be provided with separate foundations with a joint at their junction with the abutment.

Wing walls may be of solid type, the wing walls should be designed to withstand the earth pressure in addition to self-weight. Wing wall shall be of sufficient length to retain the roadway to the required extent and to furnish protection against erosion. Weep holes to be provided for return / wing wall

Provide dirt wall to prevent the earth from approaches spilling on the bearings. A screen wall of sufficient depth (extended for at for at least 500 mm depth into the fill) to prevent slipping of the backfill in case the abutment is the spill through type.

For dirt wall of spans more than 6m, the the dirt wall shall be reinforced.

Pier and abutment caps shall be in reinforced cement concrete (M20 Grade). The thickness of cap over the hollow pier or column type of abutment should not be less than 250 mm but in case of solid plain or reinforced concrete pier and abutment, the thickenss can be reduced to 200 mm.

Table:8.13. Length of Return (IRC SP : 20 - 2002, Page No. 138)

Hieight of fomation at abutment above bed level, (in m)	Length of Return (in m)
2.5	3.75
2.5 to 3	3.75 to 4.5
35	5.25
4	6

8.10.3.4. WEEP HOLES AND WATER SPOUT :

Weep holes are provided to prevent building up of hydrostatic pressure behind abutments and wing walls.

There may not be any need for weep holes and waterspouts in small span culverts. However, local practices prevail on size and spacing of weep holes, which may be followed.

If the height of abutment and return over bed level is more than 2m, weep holes should be provided 150 mm above water level (LWL) or ground level (GL) whichever is higher. In case of stone masonry, weep holes of 150 mm dia or 80 x 150 mm size in 1 : 20 slope should be provided at required intervals (Refer: IRC:40)

For 5 m and 6 m span one waterspout of 100 mm dia should be provided in the centre of slab on either side of the deck.

Adequate number of weep holes at spacing not exceeding 1 metres in horizontal and 1 metre in vertical direction staggeredly. The lowest row of weep holes shall be provided 150 mm above low water level or lowest ground level whichever is higher.

The inlets of all weep holes should be surrounded by loose material

100mm dia AC pipe may be provided for Abutments.

One Drainage Spout to be provided on either side of the centre of the deck slab for the culvert more than 4m span.

The down spouts shall be not less than 100 mm n diameter and shall be of corrosive resistant material such as galvanised steel with suitable clean-out fixtures.

The spacing of drainage spouts shall not exceed 10 m.

8.10.3.5. Extent of Back fill: The extent of back fill to be provided behind the abutment should be as illustrated below in the fig: 8.5.

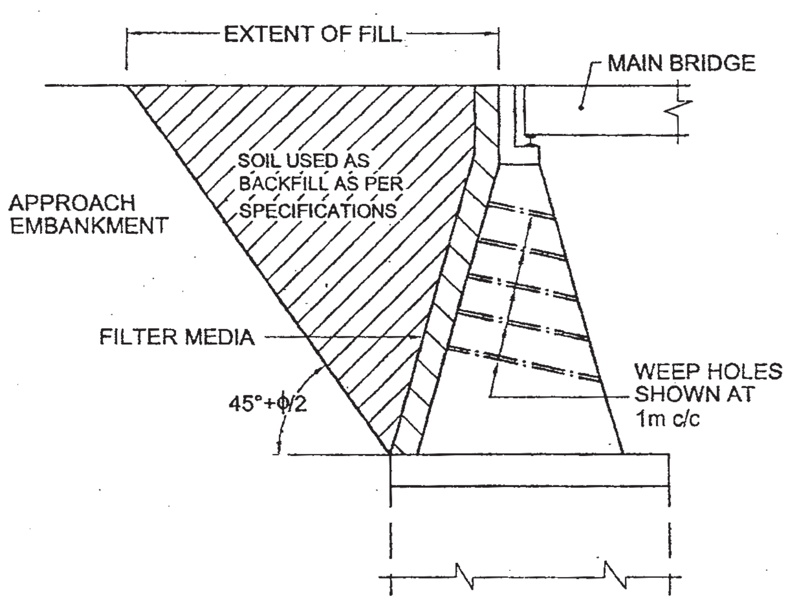


Fig: 8.5. Extent of Back fill

8.10.3.6. SUPERSTRUCTURES

Super structure of a bridge that directly supports the traffic and facilitates its smooth uninterrupted passage over natural / man made barriers like rivers, creeks, railways, roads etc., by transmitting the loads and forces coming over it to the foundation through sub structure.

8.10.3.6.1 REINFORCED CONCRETE SOLID SLABS

Set out dimension, lines and level and check with respect to permanent reference lines and permanent bench marks.

Where adjacent span of slab has already been cast in place, expansion joint and filler board abutting the already cast span shall form the shutter for the adjacent span.

Cast whole of the slab with reinforcements embedded for road kerbs and railings.

Provide wearing coat after the deck slab has been cast true to lines and levels.

Minimum clear cover for reinforcement may be of 25mm, both for deck slab and bed block.

8.10.3.6.2. RCC BOX CELL

Choose box culvert when SBC of soil is less than 150 KN/m^2 and when angle of friction is less than 15^0.

Prepare M 10 grade CC bearing surface Keep the raft in bottom of box cell 300mm below the lowest bed level.

Place the reinforcement cages in the shuttering.

Construct box section in M25 concrete or as specified with a maximum of one construction joint located in the web below the fillet between deck slab and web.

Carryout concreting operation continuously upto the construction joint and ensure proper compaction.

Provide pressure relief pipes of 100mm Ø. Mark an area of 500mm x 500mm below the pressure relief pipe in the form of inverted filter.

Provide cut off walls and protective apron.

Provide earth cushion and / or pavement on the top slabs (carriage way)

Provide 400mm thick PCC parapet.

8.10.3.6.3. COMPOSITE TYPE (RCC DESK SLAB ON STEEL GIRDERS)

Choose composite type bridges in hilly areas or where problem of centering are foreseen for casting of superstructure.

Provide shear connectors of appropriate size and spacing between the steel girder and RCC deck to ensure composite action.

It shall conform to IRC 22 & IRC 24.

Carryout painting and protective coating on structural steel components in accordance with IS 1477 with a minimum of three coats of paints or a metal coating followed by two coats of paints.

8.11. Concrete for Structure

Methodology :

i) Formwork and reinforcement contained in it shall be cleaned and made free from standing water, dust, snow or ice immediately before placing of concrete.

ii) For works, concrete shall be mixed in machanical mixer complying with IS : 1791 and IS : 1219 fitted with water measuring device. Mixing shall be continued till materials are uniformly distributed and uniform colour and consistency of entire mass is obtained. Further each individual particle of coarse aggregate shall show compelet coating of mortar containing its proportionate amount of cement. If there is segregation after unloading from the mixer, the concrete shall be remixed for not less than 2 minutes.

iii) After mixing, concrete shall be transported to formwork as quickly as possible. Concrete shall be so transported and placed that no contamination, segregation or loss of its constituent materials occur. Workability should also be maintained and the concrete (ensure that) shall not be dropped from more than 1.5m height.

iv) The concrete shall be compacted before the initial setting of the concrete but not later than 30 minutes of its discharge from the mixer.

v) Concrete shall be laid in horizontal layers to a compacted depth of not more than 450 mm when internal vibrators are used and not more than 300mm in other case.

vi) Concrete shall be thoroughly compacted by vibrations using internal (needle) vibrators of suitable size or form vibrators during placing and worked around the reinforcement, embedded fixture and into corners of the form work to produce dense, homogeneous, void free mass having face with required surface finish.

vii) After one or two hours of concreting, the concrete shall be protected from thick drying by covering with moist gunny bags, canvas, Hessian or similar material. After 24 hours, all exposed surfaces of concrete shall be kept continuously in a damp or wet condition by ponding or by coverting with a layer of soaks, canvas, Hessian or similar materials and shall be kept constantly wet for a period of not less than fourteen days from the date of placing of concrete.

8.12. APPURTENANCE

8.12.1. WEARING COAT

Both bituminous and concrete pavement used in the adjacent road works, are carried over culverts and minor bridges as wearing surface. However, separate bituminous or cement concrete wearing coats are to be laid on RCC slab bridges.

Use 20 mm thick premix carpet with seal coat as bituminous wearing coat on culverts having earth cushions and pavements carried over such culverts.

On minor bridges and culverts without earth cushion, provide 40 mm thick bituminous macadam (BM) covered with 20 mm thick premix carpet and seal coat.

In case where cement concrete pavement is provided, the same shall be carried over the hume pipe or box culverts.

Provide 75mm CC wearing coat of M30 grade for isolated RCC slab bridges or submersible structures.

Keep a cross slope of 2.5 percent for deck slab level in longitudinal profile for drainage and ensure curing earlier to prevent formation of shrinkage cracks.

8.12.2. BEARING AND EXPANSION JOINTS

For span up to 3.00m : Expansion joints may not be provided. The top of abutment cap and the face of dirt wall (on slab side) are however coated with a layer of bitumen.

For span between 3.00-6.00m : For spans between 3.00-6.00m a premoulded bituminous sheet such as shalitex board of 12mm thickness may be provided. In the parapet wall it is desirable to provide a vertical joint in the masonry wall at the location of end of deck slab. Thus the parapet wall shall have 3 parts viz. the central part over deck portion and two side parts over return walls. Corresponding joint is also necessary in the coping over parapet wall.

Provide only elastomeric bearings for RCC slab brides of span length more than 10m conforming to IRC 83 part II.

Provide 5 mm thick tar paper bearing in between abutment bed block and deck slab for RCC slab brides of span less than 10 m.

Make provision for robust, durable, watertight and replaceable expansion joints.

8.12.3. RAILING / PARAPETS

Adopt all pipe section and steel elements of railing conforming to IRC 1239 after galvanizing.

Ensure proper matching of railing at abutting joints.

For culverts, where parapet walls are provided they shall be of plain concrete M15 grade or brick or store masonry with 450 mm top width.

8.12.4. APPROACH SLABS

When overall length of CD is less than 30m, approach slab is not necessary. However it may be desirable to provide a pavement for entire formation width for a length of 3.6 m behind abutment, between returns.

When specified, adopt a minimum length of 3.5m and minimum thickness of 300mm for approach slab. Provide a 150mm thick base in M10 concrete for approach slabs.

Provide 12mm dia steel bars at 150mm in both directions at both top and bottom of approach slab and execute concreting work.

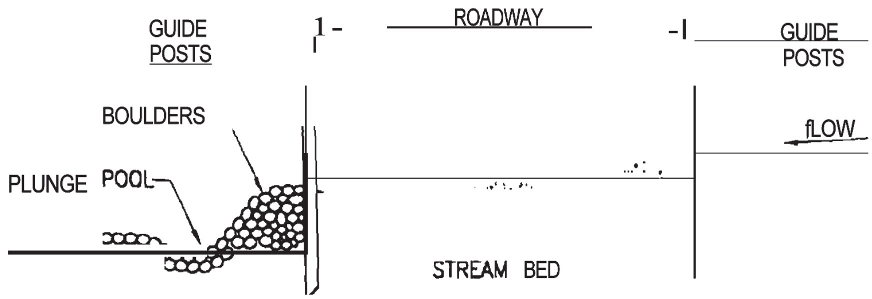
8.13. Types of Submersible Structures :

1. Fords
2. Causeways
3. Submersible bridges

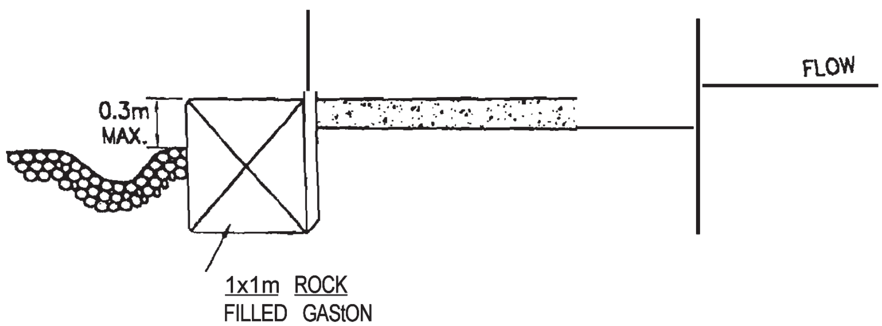
8.13.1. Fords

Fords are unpaved structures and are suitable only for roads having very low volume of traffic. These are the simplest form of crossings where the stream is wide and shallow, velocity of flowing water is low and bed surface is relatively firm.

In case the bed surface is not firm enough and not capable of carrying the vehicular traffic, the bed can be strengthened and made more even with buried stones just below the bed surface. If the stones are likely to be carried away in flow, this is prevented by construction of barriers made of suitable size of boulders or wooden piles.Boulders (neither too large which may result in scouring of bed nor too small likely to be carried away by flow) are placed across the river bed at down stream side of the ford to filter the flow of water and retain small size particles of bed material like sand, gravels etc. resulting in a more even surface for vehicular traffic. Fig.8.6 shows a typical cross-section of such type of ford.



(A) FORD WITH DOWNSTREAM BOULDERS



(B) FORD WITH DOWNSTREAM GABION

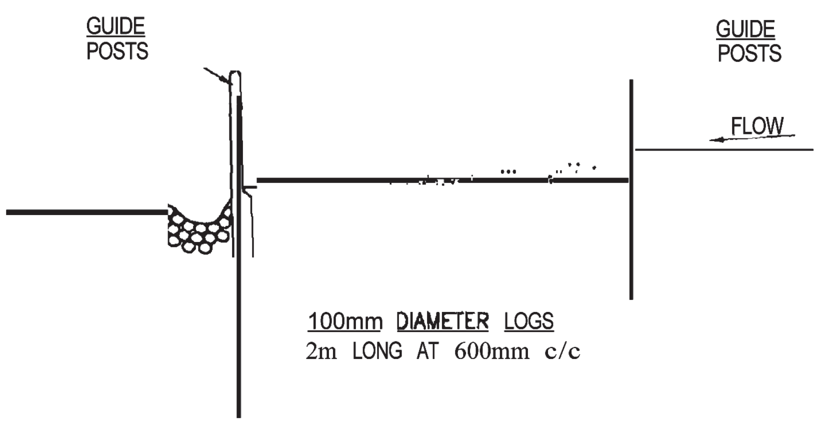


Fig: 8.6.(C) Ford With Timber Posts

Fords(i.e. unpaved causeway),though the cheapest type of crossing, should be avoided as far as possible and its adoption should be limited to sites where stream is wide, shallow with depth of water not more than 200mm, velocity of flow is low (less than 2 m/sec), bed is firm, volume of traffic is low and the water is not likely to become muddy due to the traffic, endangering the aquatic life in the watercourse or the environment.

8.13.2. CEMENT CONCRETE CAUSE WAYS

A causeway may not be a small bridge (length less than 30 m) but is a low cost cross drainage work of longer length. These are so built that the period of interruption to traffic during rainy season is short. The outer width of causeway should be equal to roadway width.

There are mainly three types of causeways:

(a) Flush causeway

In this type of causeway which is also called paved dip or road dam, the top level of road is kept same as that of bed level of the channel. It is suitable where the crossing remains dry for most of part of year i.e. the stream is not perennial. Flush causeways are not suitable for crossing the streams with steep bed slopes causing high velocity even in low floods. The causeway covers the full width of the channel as shown in Fig: 8.7.

It is a paved dip or road dam of a roadway, build to cross a shallow water course. Keep top level of floor of causeway same as that of bed of water course and build cut off walls having PCC footing of 150mm thickness in M15 grade laid on a layer of 100mm thick lean concrete (M10) .

Adopt a PCC slab of minimum thickness 200mm (of minimum M30 grade) as paved dip. Provide construction joints 4-6 m apart and seal them with polysulphide.

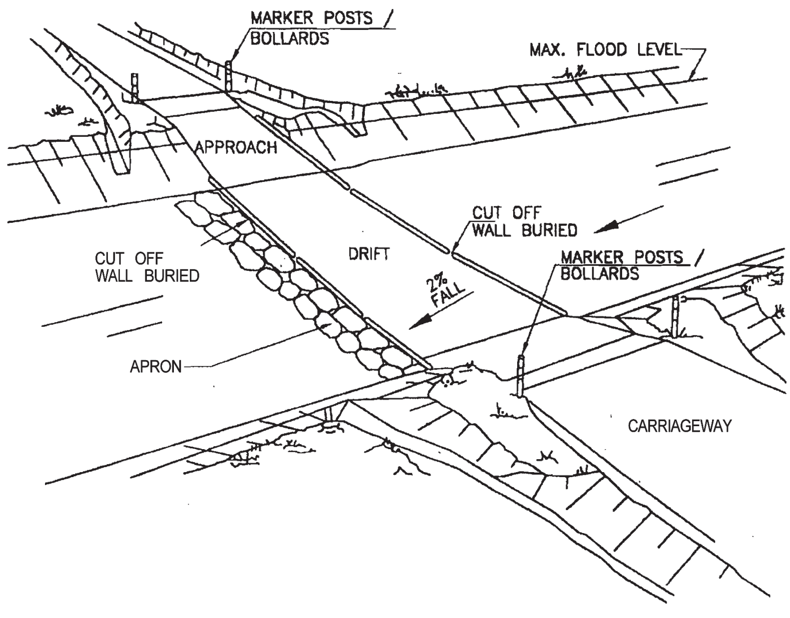


Fig: 8.7. Typical Features of Paved dip/Flush Causeway

(b) Vented causeway

A causeway provided with vents to permit normal flow of the stream to pass under the causeway is known as vented causeway. Vented causeways are classified as low vented causeways and highvented causeways.

Causeways for crossing a wide watercourse with low banks and having not too large but perennial flow should be proposed with caution. These should be proposed on rural and less important link roads, not likely to generate much traffic in near future due to situations like dead end, low habitation and difficult terrain conditions. Causeways may be proposed on streams of flashy nature with high frequency of short duration or at sites where construction of submersible bridge is not economically viable.

(i) Low vented causeway

Low vented causeways are provided to cross quasi-perennial streams having sandy beds in areas with annual rainfall less than 1000mm and where the carriageway of a flush causeway would be liable to get slushy due to post monsoon flow in the stream. The height is generally less than 1.20m above the bed of the watercourse. In exceptional cases, the height may be 1.50m above the bed level. Small size of vents in the form of hume pipes, short span slabs/R.C.C. Box cells are provided in the width of stream. The sill level of vents is kept about 150mm-300mm below the average bed level of the stream.

(ii) High vented causeway

High vented causeway is provided when a road crosses a stream having one or more of the following characteristics:

(i) Sizeable catchment area with annual rainfall more than 1000mm

(ii) Depth of post monsoon flow is more than 900mm

(iii) Flow is perennial but not large

(iv) Banks are low necessitating construction of high embankment in the stream bed from considerations of the free board in non-submersible portion as well as geometric standards of approach roads

The height of the causeway above the bed is generally kept between 1.5 m to 3.0 m and larger size of vents comprising of hume pipes or simply supported/continuous R.C.C. slab super structure over a series of short masonry piers or series of arches or boxes with individual spans less than 3m are provided.

8.13.3. Material Specifications

13.3.1. Materials used in construction of submersible structures shall conform to relevant IRC Codes.

13.3.2. In view of the likelihood of the structure getting submerged during floods, the following additional criteria may also be considered for adoption;

(i) Minimum strength of concrete, cement contents (kg/cum) and maximum water cement ratio should be as suggested in Table: 8.14.

Table: 8.14. (IRC SP : 82 - 2008, Page No. 120)

Structural Member	Minimum strength of concrete	Minimum cement content (kg/cu.m)	Maximum water cement ratio
PlainCement Concrete members (PCC members)	M20	310	0.45
Reinforced Cement Concrete members (RCC members)	M25	360	0.40
Prestressed Concrete member (PSC) .	M35	400	0.40

Notes:

(i) The above minimum cement content is based on 20 mm aggregate (nominal maximum size). For larger size aggregates, it may be reduced suitably but the reduction should not be more than 10 percent or 30kg percu.m which ever is lower. For 12.5 or 10mm size aggregates, it shall be increased suitably but the increment should not be less than 10 percent or 40 kg per cu.m which ever is higher.

(ii) Hand mixed concrete shall be avoided but if unavoidable for small isolated causeways, the cement content shall be increased by 10 per cent.

(iii) Leveling course for masonry abutment, pier, return/wing/toe wall should be M15.

(iv) Concrete for piers should not be leaner than M30.

8.13.4. Design aspects :

(i) Road top levels above bed should be as low as possible as per guidelines for different types of openings.

(ii) Vent opening below road top level.

(iii) Headwall shape in elevation-trapezoidal, blending smoothly with the natural cross-section of the watercourse with desirable grade 1 in 30.

(iv) Provision of apron for downstream protection in erosive strata.

(v) It is preferable that the downstream headwall should have batter in the outside, i.e., on downstream side.

(vi) It is also preferable to provide rounding at the outer corners to both the headwalls.

(vii) It is preferable to provide slight camber to pavement on one side only, i.e., slopping to downstream side only.

(viii) Road top level and top of coping above headwalls should be the same.

(ix) Lower limit of 30 per cent of the area below RTL.

(x) And lower limit of 15 per cent for scanty rainfall area.

8.13.5. GUIDELINES FOR DESIGN OF CAUSEWAYS

General principles

A causeway is a structure midway between a full-fledged bridge (permitting full opening to flood waters) and a natural crossing obstructing no water way at all. A full-fledged bridge provides uninterrupted passage for traffic throughout the year while a natural crossing provides passage only during the dry season of the year.

A Causeway provides passage to the traffic in a major part of the year except during the flood season. An engineer has to understand its shortcomings and take appropriate counter measures to make best utility out of it and effect maximum economy while designing it.

It is expected that a causeway remains undamaged during maximum flood and remains functional during the rest of the time. There is inter-relationship among road top level (RTL), opening provides below RTL (Vent way) and length of the protected bed (Horizontal length of face wall and rising portion of the face wall on both banks). For evolving most economical, stable and hydraulically efficient designs, different

trials with the above three parameters (i.e., RTL, Vent way and extent of protected bed) have to be undertaken. For successful prevention of out-flanking, it is necessary to carry out proper calculation of the number of vents and length of rising face walls. It is very important to note that in a vented causeway, the rising face wall plays a very important role in prevention of out flanking. For any natural watercourse, the most efficient hydraulic section is hyperbolic open channel. Nature invariably adapts the same sections. In road geometry, it is difficult to use this section in its true shape. So a modified shape in the form of trapezoid is best adapted amongst all other practicable shapes. This shape is achieved by rising face walls on the flanks and keeping the central portion of the face wall at one level. The entire zone between these face walls should be paved and is generally referred as protected bed.

Component parts

Simply raising the road top level of the causeway never ensures facility to cross at higher floods unless adequate openings are provided. Otherwise it amounts to construction of a road dam raised above the streambed which fails invariably. If due to cost consideration, it is not possible to provide full openings for the floodwaters, the only alternative left is to reduce the height of causeway to the barest minimum. In all flow conditions and the floodwater up to RTL is the most critical condition especially for the submersible bridges. If the construction is low, the flow becomes smooth, and the velocity remains under control, thereby the damages are less. In all the types of causeways, the RTL should, therefore, be kept as low as practicable.

Openings or vent area

Vent area or openings provided below the RTL plays a great role in operational and hydraulic efficiency of the structure. It is desirable to provide vent area of at least 30 per cent of the area obstructed at RTL. Higher values of vent area will reduce the expenditure on the raised face walls and protected bed. In scanty rainfall areas, i.e., annual rainfall less than 750 mm, the vent area could be brought down to 15 per cent.

In case where the causeway is located at the existing natural crossing, the obstructed area should be calculated on the suitable defined cross-section of the steam immediately near the crossing by transferring the road top level on that section.

Openings may be provided by Hume pipes, RCC slabs, Arches or RCC box cells. In erosive strata these openings should be equally spaced through out the channel portion. The spacing could be designed in central zone of causeway. In case of rocks

and other non-erosive strata, the spacing may be suitably changed and openings may preferably be provided in the lowest portion.

In case of openings with pipes it is desirable to keep down stream sill of the pipes 300 mm below the average bed level and to lay them to the shape of the stream. In order to keep down the RTL and increase the percentage value of opening, the height of cushion above the pipes should be as low as possible. To enable such reduction from structural point of view, it is desirable to provide cement concrete of MI5 grade or stone paving on the top of pipes. In low rainfall areas where frequency of floods is less, a cushion with WBM and Penetration Macadam also serves the purpose. With these specifications the height of cushioning above pipes can be reduced to 225 mm.

Face walls and protected bed

Major portion, of the floodwater has to be allowed to pass over the headwalls of the causeways. The structure should, therefore, be strong enough to avoid damages during the floods. In order to keep velocities at the downstream, in desirable limits and avoid outflanking, cross-section of flow should be adaptable to nature as explained earlier. This is achieved by providing raised face walls to a certain level and protecting the paving up to that level.

It is desirable to keep the obstruction below 30 per cent to ensure sound behaviour of the hydraulic structure. Taking the cue from the same, if the headwalls are raised and anchored into the bank up to a certain level, it will provide additional area over the road top and limit the gross obstruction to flow at 30 per cent. This would result into a stable structure and will not lead to outflank.

Protective apron due to 70 per cent obstruction at road level, a causeway acts, like, a weir and an increase in velocity of flow causes scouring on the downstream side. In soils prone to scouring, protection of the downstream side bed is essential to protect the foundation of the headwall.

Protection may consist of a stone apron and toe wall. Protection should be provided for the full width of the stream at the causeway location.

1) For velocities through pipes up to 2.00 cm/sec and an afflux up to 450 mm, a 2.5 m long apron with 450mm thick rubble mat and toe wall should be provided.

2) For velocities through pipes more than 2.00 cm/sec and an afflux up to 900 mm, a 4.00 m long apron with 900 mm thick stone mat up to 2.00 m and then same reduced to 300 mm at the toe end with toe wall, should be provided.

3) In no case, the apron length should be less than three times the height of vented causeway above the apron level.

Road crust or paving over causeway

Since a causeway is expected to allow the flood waters to pass over it and is also expected to serve the traffic immediately after the flood recedes, the road surface on the causeway should be so chosen, that it does not get damaged due to frequent overtopping.

Sufficiently stable pavement should be provided for the full width of the causeway and the protected bed portion. For approach in cutting, paved side drains should be provided and portion up to 1.5 m height along the side slopes should be provided with rubble pitching. Similarly, paving over causeway may comprise of:

1) Cement concrete pavement laid over WBM.

2) Stone set pavement on suitable surface.

3) Rigid pavement with thin carpet.

8.13.6. DESIGN PROCEDURE AND WORKED OUT EXAMPLE FOR A TYPICAL VENTED CAUSEWAY

I. Important components of a vented causeway are vents, bed protection, raised face walls and paved road surface, which together ensurestability and prevent outflanking. The flow conditions are analyzed with reference to top of the protected bed and if the percentage obstruction to flow at the Road Top Level (RTL)/decklevelis keptbelow60%andatthe most 70%, then normally no outflanking would take place. At flood levels higher than the road top level, the percentage obstruction goes on reducing and the structure will be safe.

The critical conditions for design are:

(i) When the flow is at RTL

(ii) When the flow is at HFL

II. Step by step procedure:

(i) Collect normal hydraulic data, such as, catchment area, annual rainfall, HFL, site plan, L section, tide level, etc.

(ii) Collect hourly/daily record of flood levels for a representative monsoon period and plot it on a graph with maximum flood level on vertical axis and date / month wise on Horizontal axis.

(iii) Plot defined cross-section in the vicinity of proposed site to a natural scale.

(iv) Plot cross-section of crossing at proposed location to the natural scale showing soil conditions.

(v) With the help of the graph as explained in step (ii) above, determine the lowest required Road Top Level so as to satisfy the requirements of frequency and duration of submergence indicated in Table. 8.15.

(vi) Fix Road Top Level (RTL) keeping in view following guidelines:

a) It should be as low as possible but higher than the lowest RTL determined vide step (v) above.

(b) In case of box or simply supported slab/ arch type structures,the vent size should not be less than 1.5m horizontal and 1.2m vertical. Internal diameter of circular corrugated / RCC hume pipe shoul not be less than 1.0m or 1.2m preferably.

(c) Cushion over the structures should not be less than thickness of proposed road pavement subject to minimum 300 mm.

(d) Sill level of vents should be 300 mm below the lowest bed level (LBL) with longitudinal slope (in the direction of flow) nearly same as that of stream bed subject to minimum of 1:100.

(e) The Protected Bed Level (PBL) may be kept equal to the sill level of vents.

(vii) In the case of less important crossings, if it is decided by the competent authority to skip fixing of the lowest required Road Top Level as per rigorous method vide step (v) above, for' first trial a level difference of say 1.5m may be assumed between RTL and PBL.

(viii) Transfer RTL fixed as above to the defined cross-section as first trial.

(ix) Calculate area below RTL at the defined cross-section.

(x) Fix vent area i.e. about 40% but minimum 30 percent, in normal rainfall areas and minimum 20% incase of scanty rainfall areas.

(xi) Determine number of pipes/number of spans and span length of vents.

(xii) Fix length of horizontal portion of the face wall and length of rising face wall keeping in view following guidelines:

(a) Length of horizontal portion should be equal to bed width of the channel plus minimum 4m.

(b) Gradient of rising face wall should be between 1:15 to 1:30.

(xiii) Calculate the unobstructed natural are area of flow at the defined crosssection between the bed level and the proposed RTL = A_1

(xiv) Calculate the area of flow available at vented causeway upto protected bed level = A_2

(xv) The percentage obstruction to flood water is calculated by following expression. $= ((A_1-A_2) \times 100) / A_1$

(xvi) If the obstruction is not less than 70 percent, then steps are repeated by increasing the RTL by 200mm.

(xvii) The proposal, with percentage obstruction less than 70 percent is then finalized.

(xviii) This should be checked for flood level at design flood level, for which condition the percentage obstruction should be less than 30%.

8.13.7. Worked out example

Determine water way required for the following conditions:

Design discharge	= 682.6 cumecs
Bankwidthat defined cross-section	= 42m
HFL	= 102.42 m
LBL	= 98.905 m

Design

(i) Assume sill level of vents and PBL at RL 98.905- 0.300 = RL 98.605m

(ii) Assume 1 m dia pipes and RTL of 100.5 m which provides for more than adequate cushion over the hume pipes.

(iii) Area of flow at defined cross section below RTL (assuming parabolic profile of bed and channel width of 34 m at RTL).

= 34 x (100.5-98.905) x 2/3 = 36.15 sq.m.

(iv) Provide a vent area of 40% to the causeway

= (36.15 x 40) / 100 = 14.46 sq.m.

(v) Number of 1000mm internal diameter pipes required

= (14.46) / $[(\pi/4) \times (1.0)^2]$ = 18.42 say 19 Numbers

Trial (i) with 19 no. of pipes of 1000mm inner dia.

The outer dia pipe is 1150mm (i.e. 1.15m)

Clear spacing between adjacent pipes shall be 0.6 m

Length of End portion on either side (for safety)=2.0m

Total length= 19 x 1.15+ 18 x 0.6 + 2 x 2.0 = 36.65m

As 19 Nos. of 1m internal dia pipes can not be accommodated in a bed width of 34m available at the RTL, the number of pipes need to be reduced.

Trial (ii) with 17 pipes of 1000 mm dia.

Total length = 17 x 1.15+ 16 x 0.6+ 2 x 2.0 = 33.15 m

This can be accommodated with the available 34m.

Available vent area= 17x $[(\pi/4) \times (1.0)^2]$= 13.345 sq.m.

Percentage of the area of flow below RTL= 100 x 13.345/36.15= 36.92%. This is little less than 40% but is more than the that of 30%. Hence O.K.

Check for obstruction when flood level is at HFL

Assume an approach gradient of 1:30 on either side.

Width of stream at HFL = 34+2x 30 (102.42-100.5) = 149.2 m.

Area available for flow above RTL =[(149.2 +34)/2] x1.92 =175.872 sq. m.

Therefore total available area for flow =175.872+13.345 =189.217sq.m.

Area of obstruction =34 (l00.5-98.605) -13.345 = 51.085 sq. m.

Percentage obstruction =51.085 / 189.217x 100=27%

Less than 30%. Hence O.K.

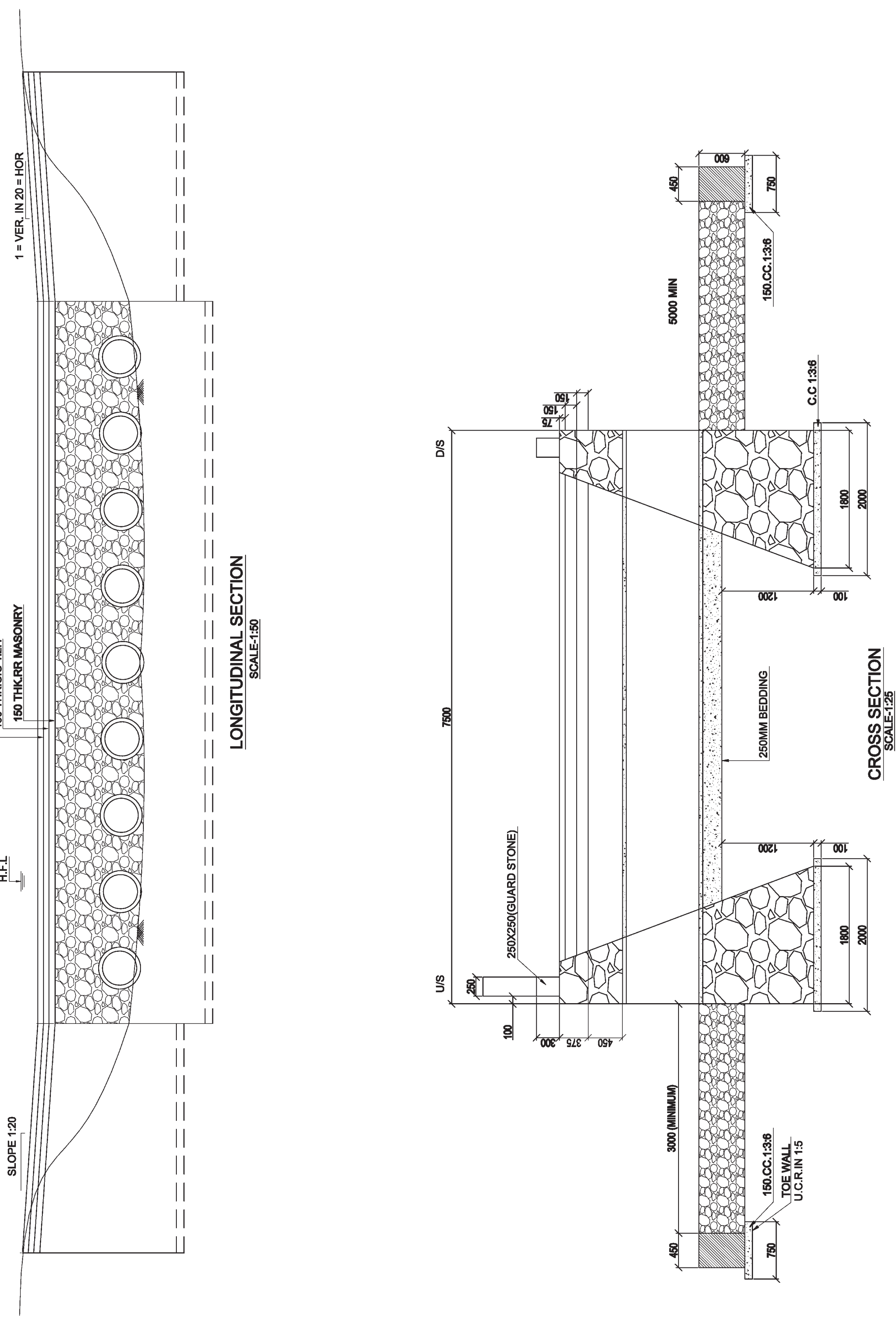


Fig: 8.8. Low Level Vented Piped Causeway

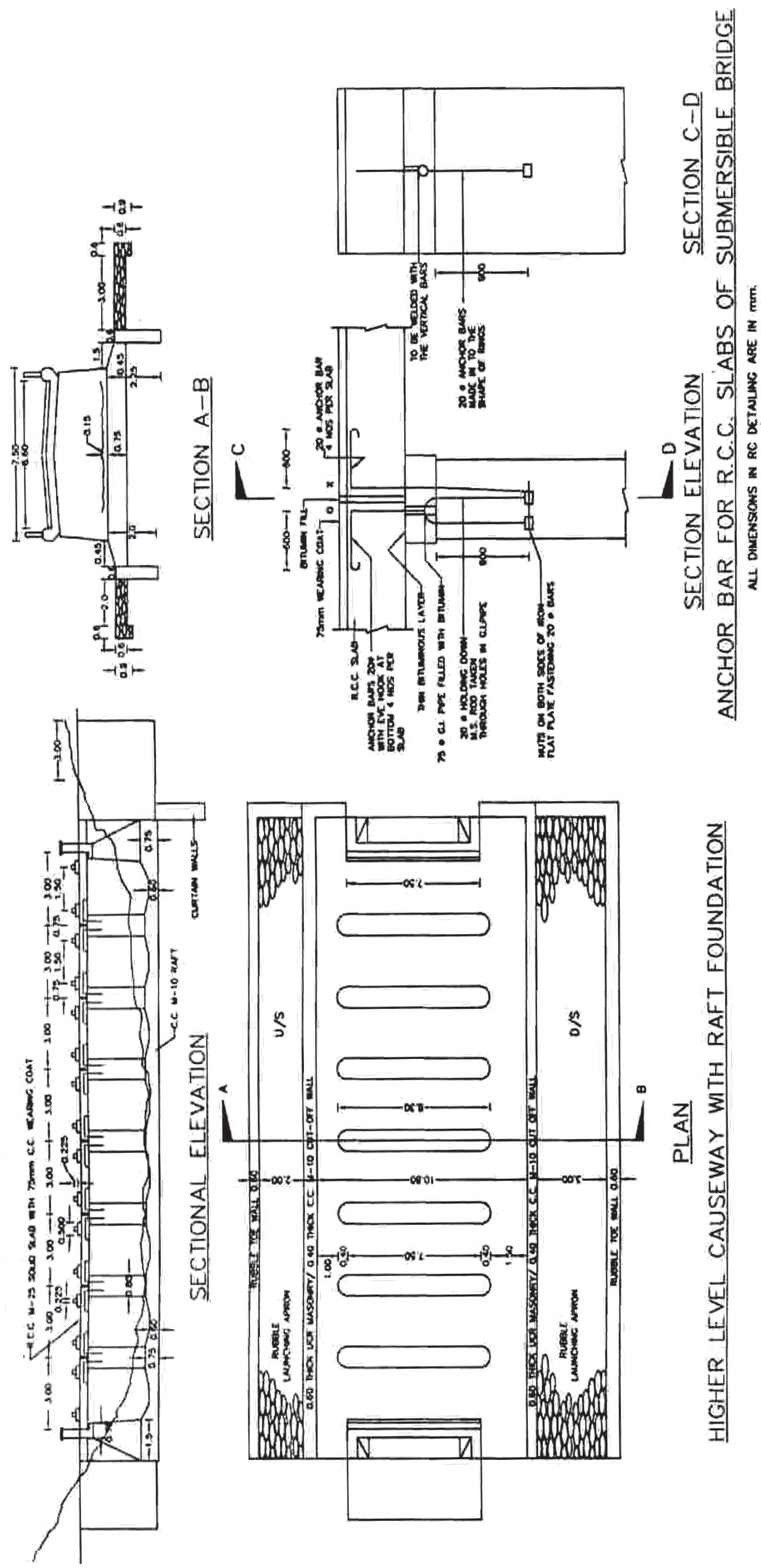


Fig: 8.9. High Level Vented Causeway with Raft Foundation on Sandy Bed

8.13.8. Submersible bridge

A submersible bridge is a bridge, which gets submerged during monsoon in high floods of short duration, but is available for use of traffic during the rest of the times.

Depending upon deck level with reference to OFL, Submersible bridge is sub-classified as

Low submersible bridge

High submersible bridge

The deck level of low submersible bridge is fixed above the OFL so as to ensure that the interruptions caused to traffic remain within permissible limits.

The deck level of high submersible bridge is fixed with reference to OFL and vertical clearance, and assuch the structure serves as high level bridge during OFL but gets submerged under higher floods with permissible number and duration of interruptions. This type of bridge is suitable for streams having large variation between HFL and OFL.

8.13.8.1. Selection of Type of Submersible Bridge/Causeway

The type of structure (i.e. high level or submersible) across a water course (Channel) has to be judiciously selected on the basis of reconnaissance inspection report and available data. The choice mainly depends on the classification of the project road, requirements of the user authority, hydrology of the water course and availability of funds for the project

Considerations in the selection of type of submersible structures

Selection of type of submersible structures (i.e.ford or causeway or submersible bridge) inter-alia depends on:

(a) Requirements of user authority and availability of funds

(b) Category, importance of road and traffic intensity

(c) Population to be served

(d) Nature of stream i.e. flashy/perennial/seasonal etc. and velocity of water during floods

(e) Duration,magnitude of floods and interruption to traffic

(f) Spread and depth of water during floods and postmonsoon period

(g) Extent of catchment area

8.13.8.1.2. Criteria for avoiding / selection of submersible structures

In the absence of any directives / guidelines by the user authority, the following criteria may be followed for selection of suitable type of submersible structures including causeways on different categories of roads.

(1) The period of permissible interruptions to the traffic due to submergence of a bridge could be 6 times in a year, the period not exceeding 24 hours if no alternative access road is available.

(2) It will be adequate to provide bridge clearing the OFL and submersible for HFL, If there is a considerable difference in OFL and HFL. The soffit level of the bridge should be fixed so as to clear the OFL with some free board.

(3) Submersible structures may not be considered for adoption in the following situations:

(i) Velocity of flow more than 6 m/sec. for streams.

(ii) Roads of economic importance, roads linking important towns or industrial areas or areas with a population of more than 10,000 where alternative all weather route with reasonable length of detour is not available

(iii) On roads which are likely to be upgraded or included, from future traffic considerations, in the National Highway network

(iv) If the length of a high level bridge at such crossings would be less than 30 m except where construction of high level structure is not economically viable

(v) If the cost of submersible bridge with its approaches is estimated to be more than approximately 70% of the cost of high level bridge with its approaches, near about the same site

(vi) If firm banks are available and approaches are in cutting or height of embankment for submersible portion of approaches is more than 2m

(vii) Where there are faults in the river bed

(viii) RCC kerb of 250 mm width should not be continuous. After 1.5 m continuous length of kerb there should be a gap of 300 mm so that flood water is discharged expediously from the top of riding surface. The size of kerbe stone used could be 500x250x300 mm.

(viii) If after completion of the submersible structures,the number of interruptions in a year caused to traffic and duration of the interruptions are likely to exceed the suggested values given in Table: 8.15. below.

Table: 8.15. Permissible Number and Duration of Interruptions

S. No.	Category of Roads	Maximum No. of permissible interruptions in a year	Duration of interruption in hours at a time
1.	State Highways, M.D.Rs., roads linking important towns, industrial estates.	6	2-6 hrs. duration, less than 2 hrs. not to be considered and more than 6 hrs. not acceptable
2.	O.D.Rs,Village Roads	6	6-12 hrs. duration, less than 6 h not to be considered and more than 12 hrs. not acceptable

Make the deck slabs heavy to withstand drag, uplift and other lateral force due to overflow and upstream pressure.

Provide necessary anchorage arrangements and chambers of 40mm x40mm for corners of all submerged elements if they are not streamlined.

Provide vent holes of 100mmϕ (with PVC pipes) to reduce the uplift pressure (minimum of three per span in both the directions).

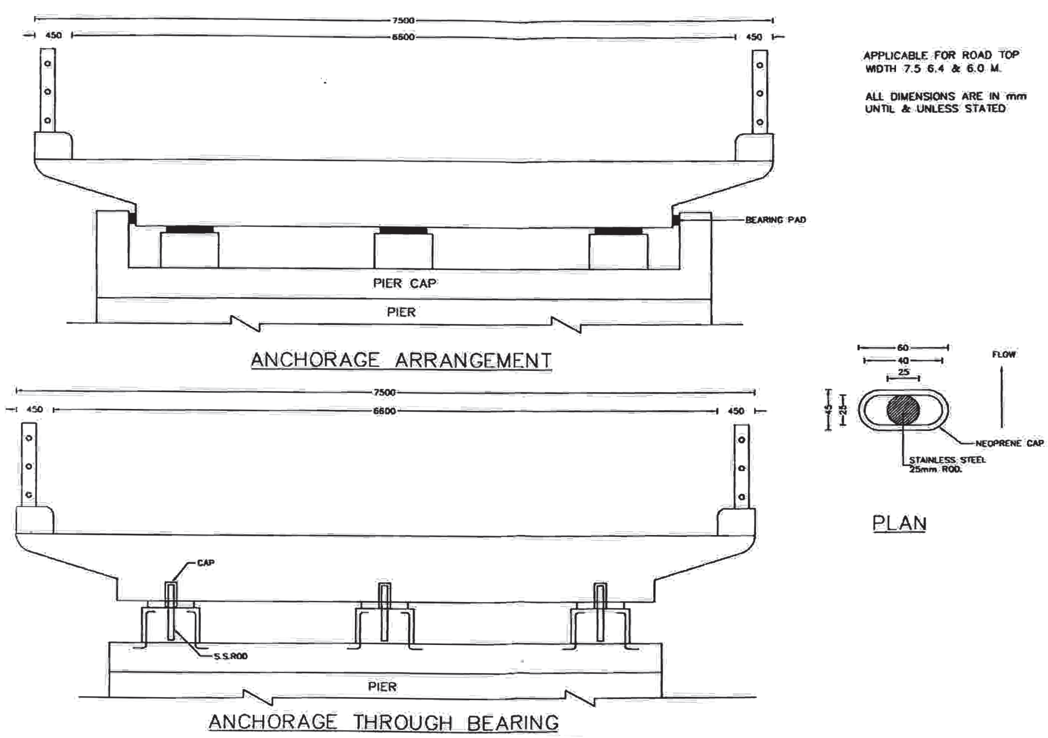


Fig: 8.10. Anchorage Arrangment for Submersible Bridge

Table: 8.16

Different types of superstructures with suggested span range suitable for submersible structures are shown below for ready reference and guidance.

S. No.	Type of superstructure	Suggested Span range (m)	Remarks
1.	Masonry Arch	1.5 to 6.0	Segmented or semicircular arch structures with short height of substructure and raft foundations upto 4.0 m have been extensively constructed in the past. Use of stonel brick masonry arches may be restricted to seismic Zones II and III with height of substructure not exceeding 6m above foundation level. The floor can be either horizontal slightly the deepest bed level or inverted shaped arch (such type of construction is most suitable for the sites having low safe bearing capacity say 150 kN/m^2. Series of arches may be used with 3rd or 5th pier designed as abutment pier. In order to reduce horizontal forces due to water current forces spandrel arch or circular corrugated/hume pipe openings may be provided in the spandrels.
2.	RCC arch	3.0 to 15.0	Larger span(not larger than 15.0 m in seismic Zone V) say upto 35.0 m requiring deep foundations may be proposed only if required. In order to reduce horizontal forces due to water current forces, spandrel arch or circular corrugated/hume pipe openings may be provided in the spandrels.
3.	RCC Box Cell type structur	1.5 to 5.0	Suitable for sites with founding strata having low safe bearing capacity say below 150 kN/m^2 .

4.	Simply supported RCC solidslab	1.5 to 10.0	Very suitable for submersible struc tures on account of ease of constructions as these are generally located in isolated places.
5.	Simply supported RCC voided slab	12.0 to 25.0	Should be preferred over T-beam andslab arrangement or R.C.C. box girder type.
6.	3 to 4 span continuous RCC closely spaced T-beam and slab	10.0 to 25.0	The spacing of the longitudinal beams is to be closer in case of superstructures for submersible bridges (say not exceeding the depth of the girder) so as to reduce the depth. May be considered in view of reduction in expansion joints and bearings provided rocky stratum is available at shallow depths
7.	Simply supported cast-in -situ RCC Box Girder	20.0 to 30.0	Prestressed concrete construction should be preferred to R.C.C. type being submersible structure.
8.	Prestressed Concrete simply supported box girder (cast-in-situ and post tensioned)	30.0 to 45.0	Minimum inside height of the cell should not be less than 1.2 m for proper maintenance.
9.	Prestressed Concrete simply supported voided slab (cast-in-situ and post-tensioned)	15.0 to 30.0	May be preferred to box type superstructures.
10.	Prestressed Concrete simply supported voided slab (precast and pre/ post-tensioned)	15.0 to 25.0	To be considered in case of water courses with high velocities.
11.	R.C.C. Rigid -Frame or Portal type 3-4 continuous spans	10.0 to 20.0	Most suitable for sites where rocky stratum is available at shallow depths.

8.13.8.2. Design aspects :

8.13.8.2.1. Constriction of Waterway

(i) Any constriction of waterway either laterally or vertically reduces the natural waterway of stream which results in change in normal flow pattern from that existing before the constriction and in afflux on upstream. Higher the constriction of natural waterway, higher will be the afflux and the velocity of flow through the vents. It is therefore, desirable to keep the constriction of waterway to the minimum in order to reduce expenditure on providing raised face walls and protection of bed. However, constriction to varying degrees becomes unavoidable, depending on the type of structure that may be selected for adoption based on various other technical and economic considerations. The constriction of water way that can be permitted in any particular case depends on several site specific conditions, the more important ones being the nature of soil in the river bed and the adopted Road Top Level (RTL) in relation to the design HFL.

(a) If the bed material is easily erodible, it would be desirable to avoid high constriction to keep the velocity of flow through the vents within manageable limits.

(b) Similarly, higher constriction can be provided for low level submersible structures like causeways but, if the depth of flow below RTL in relation to the depth below the design HFL is high as would generally be the case when higher submersible bridges are provided, the constriction must be kept low so as to keep the hydrostatic forces on the structure within manageable limits.

(i) The following recommendations to the permissible constriction may be followed:

(a) For low level submersible structures like causeways, provide a vent area of about 40 percent but not less than 30 percent of the unobstructed area of the stream measured between the proposed road top level and the stream bed. In scanty rainfall areas where the annual rainfall is less than 600 mm, the vent area can be reduced upto 20 percent to 30 percent of unobstructed area. However, the available area of flow under design HFL condition should always be at least 70 percent of the unobstructed area of flow between the design HFL and the stream bed i.e. the obstruction under design HFL condition should not be more than 30 percent.

(b) For submersible bridges, which would generally be provided with relatively higher road top level, the available area of flow under the structure should not be less than 70 percent of the unobstructed area of the stream measured between the stream bed profile and the proposed road top level.

(iii) RTL should not be abnormally high over vent opening as this causes heading up of water on u/s which in turn may result in high velocity (it can even be in the range of hyper critical) and may lead to failure and outflanking. Hence RTL should be kept as low as possible.

(iv) The increase in velocity under the bridge should be kept below the allowable safe velocity for the bed material. Typical values of safe velocities for different bed material are as below:

Type of Material	**Safe Velocity (m/sec)**
Loose clay and fine sand	upto 0.5
Coarse sand	upto 1.0
Fine gravel, sandy or shift clay	upto 1.5
Coarse Gravel / Weathered rock / Boulders upto 200mm size	upto 2.5
Larger boulders (200 - 800mm size) or rocky strata	2.5 to 6.0

(v) In case the velocity exceeds the above specified values for scourable beds, then bed protection consisting of flooring with proper cut-off wall should be provided on both upstream and downstream side on the bridge. A typical arrangement of floor protection works is given in Fig: 8.11 & 8.12.

(vi) In the post protection works, the velocity of flow under structure should not exceed 2rn / sec. The depth of drop wall should be such that it does not get undermined. If a flooring is not provided, then maximum depth of scour should be calculated carefully and depth of foundations be provided accordingly.

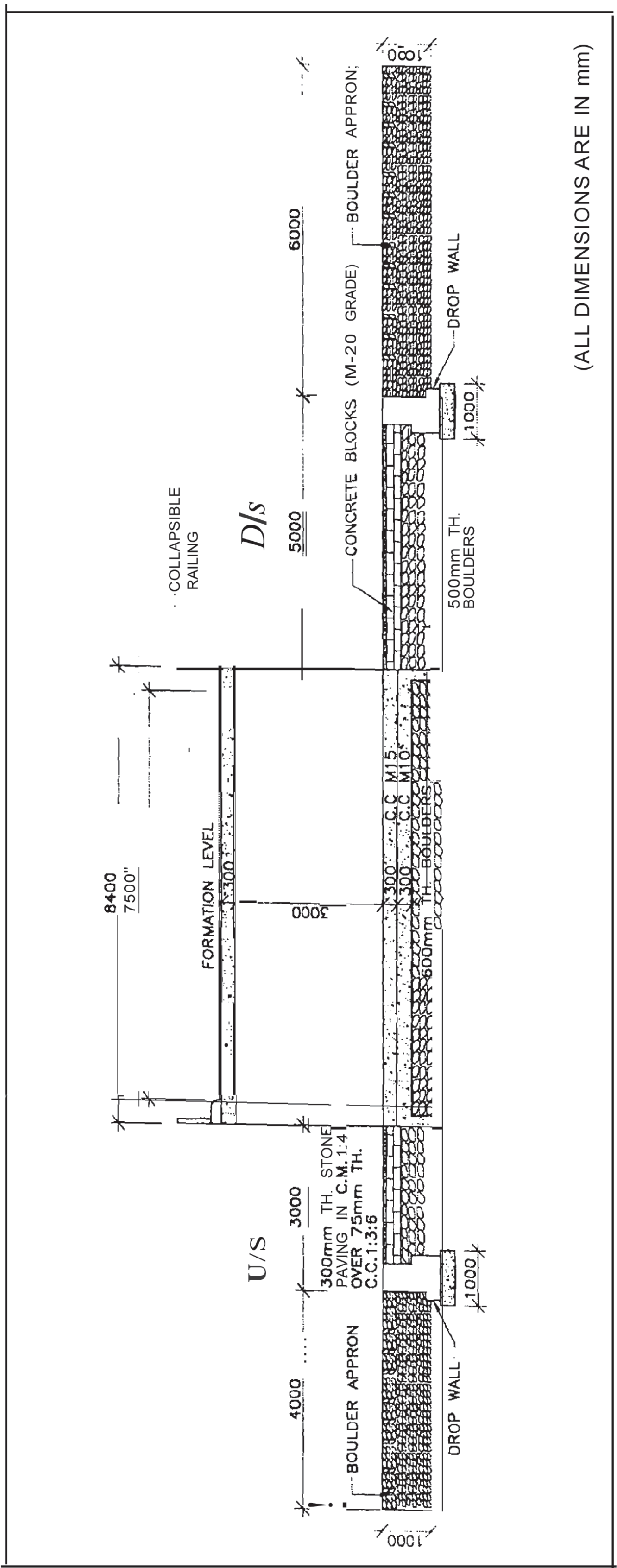


Fig. 8.11. Typical Section through Bridge Floor

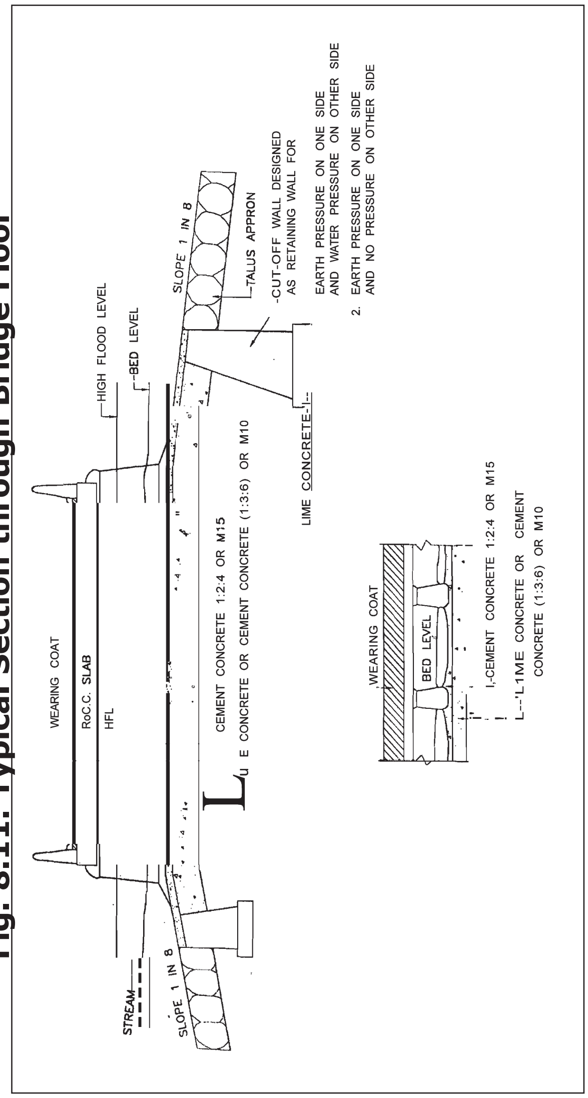


Fig. 8.12. Typical detail of florring with apron

8.13.8.2.2. Design Flood Level, Road Top Level/Deck Level

Design flood level is fixed based on the number and duration of interruptions to traffic in a year or in specific period i.e. annually /5 years etc. depending on the present volume of traffic and importance of road.

Deck level of submersible bridge is then arrived at keeping in view of two aspects i.e.

(i) Flood level during which the submersible bridge is to serve as high level bridge.

(ii) Flood level (with specific return period) during which the structure is over-topped but depth of water over the deck is safe for vehicular traffic say 200mm with number of and duration of interruptions to traffic not exceeding the permissible values.

The following may also be adoped for fixing the deck level

(i) Number and duration of interruptions to traffic may be reckoned from the flood level 200mm above RTL / deck level.

(ii) In case of submersible bridge, level of deck may be fixed so that the structure serves as a high level bridge during OFL but to be over topped during higher floods.

(iii) The deck level of the submersible bridge should not be higher than RTL of approaches likely to be submerged during floods, otherwise the approaches may be breached resulting in major portion of flow to pass through breaches in place of the main structure, and may result in change of course of active channel, extensive recurring maintenance/ repair costs etc.

(iv) RTL / deck level should be as low as possible in order to have economical design. RTL in case of flush cause ways / fords may be kept at bed level and may follow the cross-section of the channel to the extent possible.

8.14. DESIGN OF BRIDGES

8.14.1 INTRODUCTION

Bridges are designed usually for 50 years of service life. The Investigation, formulation of proposal, Design and Construction of the road Bridges require extensive and through knowledge of engineering involved.

8.14.2. BRIDGES

Bridges are classified according to

Function : Aqueduct (canal over a river), Viaduct (road or railway over a valley), pedestrian,highway, railway, road - cum- rail or a pipeline bridges.

Material of construction : Timber, masonry, iron, steel, reinforced concrete, prestressed concrete, composite or aluminum bridges.

Type of structures : Slab, beam, truss, arch, cable stayed or suspension bridges.

Inter-span structures : Simple, continuous or cantilever bridges.

Position of bridge floor relative to the superstructure : Deck, through, Half through or suspended bridges.

Method of connections : Pin connected, riveted or welded bridges.

Flow level : High level , submersible bridges.

Navigation : High level, movable - bascule, movable - swing, movable lift or transporter bridges.

Length : Culvert (less than 6.00m) , minor bridge (6.00-60.00m), major bridge (above 60.00m) or long span bridges.

Degree of redundancy : Determinate and Indeterminate bridges.

Service and Use : Permanent , temporary, military bridges.

High Level Bridge is a bridge having its bottom of the deck fixed taking into account of the vertical clearance for navigation and anti obstruction requirements. RL of Bottom of the deck (BOD) of any high level bridge is worked out by adding the sum of afflux (Usually 0.15m) and corresponding vertical clearance to the MFL at site.

That is, B.O.D	=	MFL + Afflux + Vertical Clearance
Road Level of High Level Bridge	=	B.O.D + Depth of Superstructure at centre + Thickness of wearing coat
Length of Wing wall	=	Road Level - sill level + 0.30m
Height of Wing wall	=	Road level - sill level - Camber

Span center to center is the centre-to-centre distance between the two successive expansion joints or the centre-to-centre distance between the expansion joint at abutment location and the expansion joint at adjacent pier location.

Effective span is the distance between the centre to centre of seating widths of deck or it is the sum of the clear span and width of seating of deck in respect of solid slab super structure. Effective span in respective of T.Beam cum slab superstructure will be the centre to centre distance of bearing.

Overall Span is the length of the superstructure along the direction of traffic. i.e., it is the distance arrived by deducting the thickness of expansion joint from the centre to centre span.

Afflux : The afflux at a bridge is the heading up of the water surface caused by it. it is measured by the difference in levels of the water surfaces upstream and downstream of the bridge.

8.14.3. SELECTION OF SITE

(Ref: Page No.10 of MORT&H Pocket book for Bridge Engineers, Ref.2) While selecting the site, the following factors are to be considered.

a. The permanency of the channel

b. Width of the channel

c. Large average depth of the water as compared to maximum depth

d. Site location with gorges (may preferably be avoided).

e. Straight reach on U/S & D/S of bridge site is to be preferred

f. Sharp bends on the U/S of the bridge site may preferably be avoided

g. The site should be free from island or obstruction in river bed both on U/S and D/S

h. Selection of site should also be away from confluence of tributaries

i. The presence of high and stable bank is to be preferred

j. Right angle crossing is to be preferred

k. Curves in approaches and also in the length of the structure is to be avoided

l. The distance between Railway bridge and highway bridge should be as wide as possible but not less than 400m in any case.

m. At skew crossings, skew of more than 45^0 should generally be avoided

8.14.4. BRIDGE ALIGNMENT

8.14.4.1. REQUIREMENTS

1) The alignment for new bridges & its approaches shall avoid crossing of Railway lines, water logging or seepage flows, erosion/landslide prone areas.

2) The alignment for new bridges shall pass through better soil area with good natural drainage

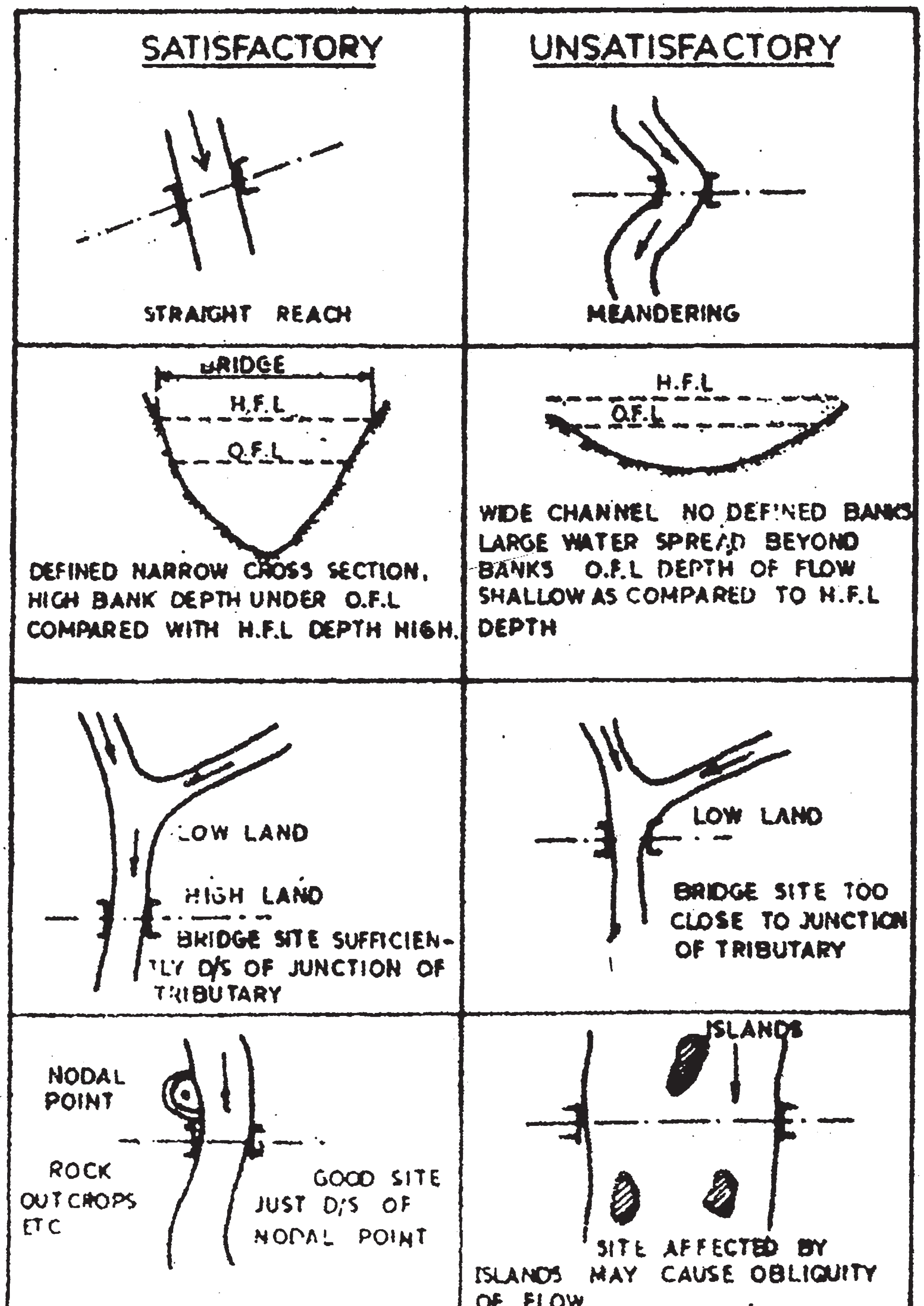
3) As far as possible the utility of the maximum length of existing roads may be explored for the proposed bridge in case of reconstruction of existing bridge.

4) The possibility of using the existing bridge as diversion road may be explored on economical basis considering cost of forming diversion road in case of reconstruction of existing bridge.

5) As far as possible alignment causing high embankment shall be avoided

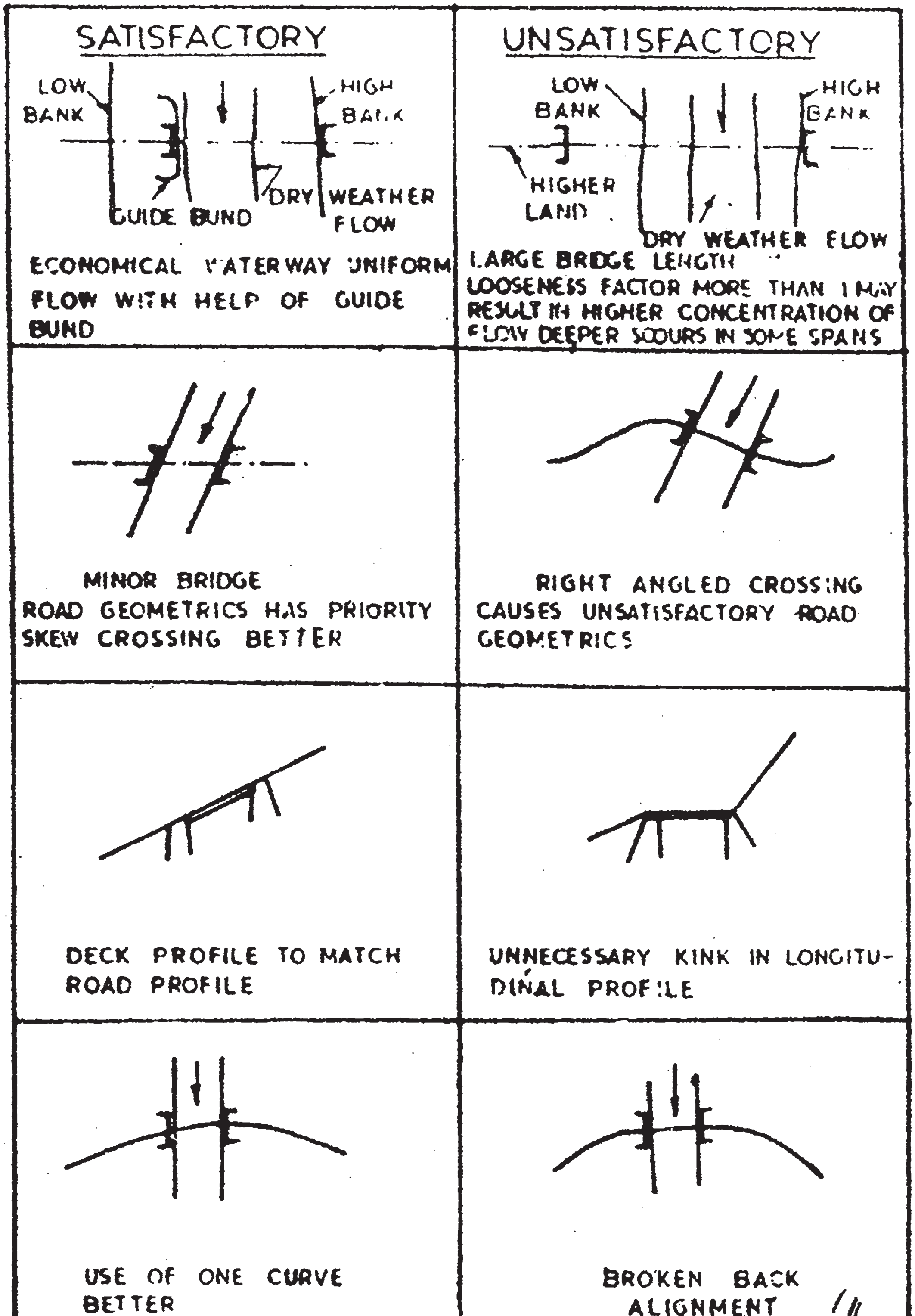
6) In vertical alignment at least 15m long level portion shall be provided from either end of wing walls, beyond which approach with falling/raising gradient is to be provided.

7) The falling/rising ramp of approach shall not be steeper than 1 in 30. In urban stretches in view of intersections at frequent intervals the maximum falling/ raising gradient of approaches may be 1 in 25 (Cl.11.2,IRC:86 1983,Ref:20).



EXAMPLES OF SATISFACTORY/UNSATISFACTORY BRIDGE SITES

Fig: 8.13



EXAMPLES OF SATISFACTORY/UNSATISFACTORY BRIDGE SITES

8.14.4.2 The horizontal alignment shall be in accordance with the following provisions:

The choice of design speed depending on the classification of road and terrain condition shall be as follows: (Table:2 of IRC:73 - 1980)

Table: 8.17

Road classification	Design Speed (kmph)			
	Plain Terrain		Rolling Terrain	
	Ruling Min.	Absolute Min.	Ruling Min.	Absolute Min.
NH & SH	100	80	80	65
MDR	80	65	65	50
ODR	65	50	50	40
Village Roads	50	40	40	35

Road classification	Design Speed (kmph)			
	Mountainous terrain		Steep terrain	
	Ruling Min.	Absolute Min.	Ruling Min.	Absolute Min.
NH & SH	50	40	40	30
MDR	40	30	30	20
ODR	30	25	25	20
Village Roads	25	20	25	20

The Minimum Radius of Horizontal curves for different terrain conditions: (Table: 16 of IRC: 73 - 1980)

Table: 8.18

(meters)

Road classification	Plain Terrain		Rolling Terrain	
	Ruling Min.	Absolute Min.	Ruling Min.	Absolute Min.
NH & SH	360	230	230	155
MDR	230	155	155	90
ODR	155	90	90	60
Village Roads	90	60	60	45

Road classification	Mountainous terrain				Steep terrain			
	Areas not affected by snow		Snow bound areas		Areas not affected by snow		Snow bound areas	
	Ruling Min	Absolute Min	Ruling Min	Absolute Min	Ruling Min	Absolute Min	Ruling Min	Absolute Min
NH & SH	80	50	90	60	50	30	60	33
MDR	50	30	60	33	30	14	33	15
ODR	30	20	33	23	20	14	23	15
Village Roads	20	14	23	15	20	14	23	15

The design of horizontal and vertical curves shall be made in accordance with IRC:38 - 1988 and IRC.SP:23 - 1983

8.14.4.3. FIELD PARTICULARS

The Following field particulars shall be collected for formulating the bridge proposal

FIELD DATA	Reference
1. Index Map showing the proposed location of the bridge - Scale -1:50,000	Cl.102.1.1 of IRC:5 - 1998
2. Key Map - Size of the drawing may be 594x420mm (A2)	Cl.6.6.2 of IRC:SP:54-2000
3. Site Plan - Scale - 1:500 - Extending not less than 100m on U/S and D/S and covering the approaches to a distance of not less than about 500m on either side.	Cl.102.1.3 of IRC:5 - 1998
4. Catchment area - Scale - 1:50,000	Cl.102.1.5 of IRC:5 - 1998
5. Longitudinal section of the stream, horizontal Scale -1:1000, vertical Scale - 1:100	Cl.6.6.3 of IRC:SP:54-2000
6. Cross section of the stream, horizontal scale - 1:1000, Vertical Scale - 1:100 At least 3 cross section on U/S, 3 cross sections on D/S and 1 at site Distance between cross sections of the river may be based on the catchment area Table 3.1 of IRC. SP:13-2004 **Catchments Area** — **Distance at which CS Should be taken** 1. Up to 3.00 Sq.km — 100m 2. From 3.00 to 15 sq.km — 300m 3. more than 15.00 Sq.km — 500m	Cl.3.3 of IRC:SP:13-2004
7. Longitudinal section along the alignment, Horizontal Scale -1:1000, Vertical scale - 1:100	Cl.704.1. of IRC:78 - 2000
8. Sub - Surface exploration - The bore log shall show the chainage of the bore holes and Reduced levels of the top of bore holes stratum encountered at various levels, soil details, N - values based on SPT (Standard Penetration Test), combined bore chart, etc.,	IRC:78 - 2000

8.14.4.4. SUB - SURFACE EXPLORATION (Ref:Cl.704.3 & appendix-2, IRC:78-2000)

The objective of sub - surface exploration is to determine the suitability of the soil or rock for the foundation of the bridge. Guidance may be taken from

1) IS : 1892 - Code of practice for site investigation for foundation

2) IS : 2720 - Methods of test for soils

3) IS : 1498 - Classification and identification of soils

During investigation, rotary drills of dia not less than 150mm shall be used. The exploration shall cover the entire length of bridge and also extend at either end for a distance of about twice the depth below the bed of the last main bridge foundation to assess the effect of approach embankment on the foundation. The sub - surface exploration shall generally extend to a depth below the anticipated foundation level equal to about 1.50 times the width of foundations in the case of soils and at least 3m in the case of sound rock.

The location of borings shall be judiciously decided in such a way that the data collected covers the entire bridge and is true representative of foundation strata and offers enough guidance to the designer in deciding the type of foundation. Generally the bores are to be taken at every location of pier foundation and abutment.

The following field test and laboratory test are required to be done.

For cohesionless soil :

Field Tests : Plate load test and Standard penetration test (IS:2131)

Laboratory Tests : Soil classification tests, index tests, density test and shear strength test etc.

For cohesive soils :

Field Tests : Plate load test, Vane shear test and Static cone penetration test.

Laboratory Tests : Classification test, Index test, Density test, Shear strength test, Unconfined compression test and Consolidation test

From rocky strata core samples shall be taken and tested :

Laboratory Tests: Specific gravity, porosity, water absorption test and compressive strength test.

The entire sub-surface exploration shall be done in accordance with IRC: 78-2000 and the bore chart should be furnished as per appendix-2. of IRC: 78-2000.

Cl.2.2.4.3 of Pocket book for bridge Engineers (MORT&H) 2000, stipulates that the depth of exploration for pile foundation shall be :

a. 1.5 times of estimated length of pile in soil but not less than 15 m beyond the probable length of pile.

b. 15 times diameter of pile in weak/ jointed rock but minimum 15m in such rock

c. 4 times diameter of pile in hard rock but minimum 3m in hard rock.

8.14.4.5 COLLECTION OF HYDRAULIC PARTICULARS

8.14.4.5.1. SILL LEVEL:

Sill level of the river at the proposed site is generally taken as 0.3m below the lowest bed level provided there is no much variation in the bed profile. Also it must be ensured that the proposed sill level is in tune with the finalized bed slope. i,e., the sill level should neither be at a higher level causing obstruction to the flow nor at a lower level causing ineffective depth of water. The sill level is an important factor for deciding the depth of flow and thereby the linear water way.

8.14.4.5.2. BED SLOPE:

For calculating the bed slope, the longitudinal section should be taken extending upstream and downstream of the proposed site indicating the levels of the bed and MFL. The longitudinal section should extend at least 500m on U/S and D/S.

Thus the bed slope(S) is arrived by dividing the level difference between the extreme bed levels on U/S and D/S on longitudinal section by the distance between the corresponding bed level locations

$$\text{Bed Slope} = \frac{\left(\text{Bed level at the farthest point on U/S}\right) - \left(\text{Bed level at the farthest point on D/S}\right)}{\text{Distance between the farthest points on U/S and D/S}}$$

8.14.4.5.3. Maximum Flood Level(MFL):

MFL is the maximum flood level of the highest flood ever recorded in the 50 years return cycle to be ascertained by intelligent local observation supplemented by local enquiry.

8.14.4.5.4. DISCHARGE:

Design discharge for which the linear waterway of the bridge is to be designed shall be based on maximum flood discharge of 50 years returns cycle (Cl.103.1 of IRC:5-1998). Normally, in the absence of reliable data for statistical analysis of floods, design discharge may be fixed on the basis of following methods or any rational method. Empirical medhods are less reliable and may be used with caution.

Discharge may be ascertained for the proposed bridge site by the following three methods at least.

1. Catchment area method (Empirical method)
2. Area- Velocity method (Slope area method)
3. Collection of data from PWD (Data including discharge, LWW, B.O.D, Sill, Catchment area, MFL for the proposed bridge, details of reservoir nearby etc)

1. Catchment Area Method : (for Chennai Region)

Using Ryve's Formula $Q=CM^{2/3}$, (P.7 of IRC.SP:13- 2004, Ref.10)

Q = Run off in Cum/Sec

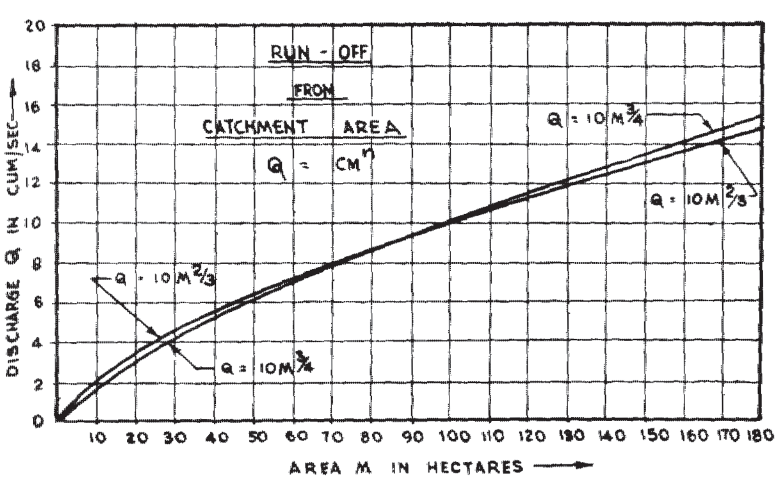
M = Catchment area in Sq.km

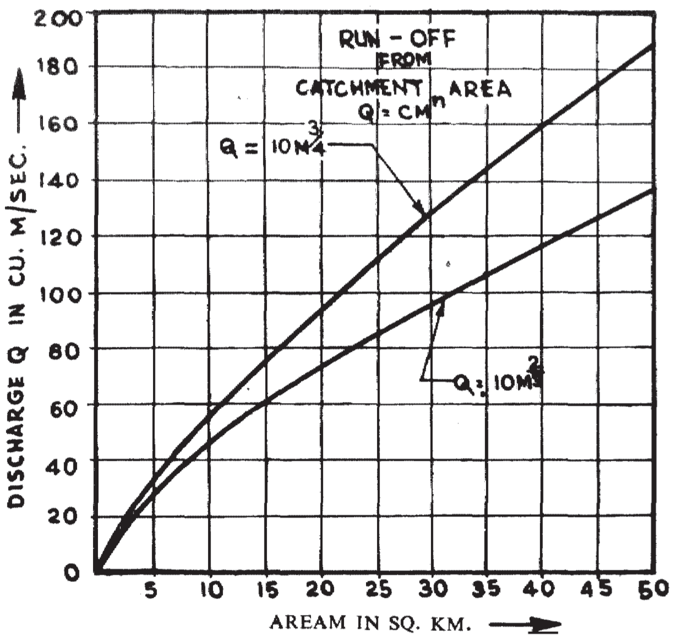
C = 6.8 for areas within 25km of the coast ,

= 8.5 for areas between 25km & 160km of the coast

= 10 for limited areas near hills.

Catchment area in sq.km can be obtained from Public Works Department.





To assist routine computations, the above two Figures have been included in which curves have been plotted to represent the equation.

$Q = 10M^n$, Two curves one for the each of the common values of n, viz., 2/3 and 3/4 have been drawn.

For Tamil Nadu, curve $Q = 10M^{2/3}$ to be adoped. This method can not yield accurate results as only one factor viz. Area of the catchment alone considered.

2. Area- Velocity Method:

The calculation of the discharge involves minimum 7 cross sections across the river with reference to MFL. The cross sections are to be plotted and the cross section area (A) in sqm and the wetted perimeter (P) in m are to be ascertained (P.17 of IRC.SP:13-2004).

The hydraulic mean depth R=A/P (in m)

Similarly, Velocity can be obtained from the following

i). Manning's Formula:

$V = 1/n \; R^{2/3} \; S^{1/2}$ in m/sec
R- Hydraulic Mean Depth S- Bed Slope

n- Rugosity coefficient

Rugosity Coefficient can be obtained from the table below

Table: 8.19

Sl. No.	Surface	Perfect	Good	Fair	Bad
	Natural stream				
1.	Clean, straight bank, full stage, no rifts or deep pools	0.025	0.0275	0.030	0.033
2.	Same as (1), but some weeds and stones	0.030	0.033	0.035	0.040
3.	Winding, some pools and shoals, clean	0.035	0.040	0.045	0.050
4.	Same as (3), lower stages, more ineffective slope and sections	0.040	0.045	0.050	0.055
5.	Same as (3), some weeds and stones	0.033	0.035	0.040	0.045
6.	Same as (4), stony sections	0.045	0.050	0.055	0.060
7.	Sluggish river reaches, rather weedy or with very deep pools	0.050	0.060	0.070	0.080
8.	Very weedy reaches	0.075	0.100	0.125	0.150

ii). Kutters Formula

V= C”RS

Where C is Kutter’s Constant,

C= (23+0.00155/S+1/n) / [1+23+0.00155/S)n/”R]

Discharge Q= A.V

The discharge may be calculated adopting cross sectional area from all the 7 cross sections. The maximum discharge among the discharges falling within the 10% variation of the average discharge may be taken as discharge by Area-Velocity method.

Maximum Discharge among the values obtained from

a. Catchment Area Method

b. Area - Velocity Method

c. Details of discharge

- may be taken as design discharge.

8.14.4.5.5. LINEAR WATER WAY (LWW):

The linear waterway required for a bridge depends on the discharge, nature of the channel, bed width, MFL Spread, etc. (Reference may be made to Cl.104, IRC: 5-1998)

Cl.104.3 of IRC:5-1998 states that " For natural channel in alluvial bed and having undefined banks, the linear waterway shall be determined from design discharge using the formula

W= CQ

W - Regime width in m (equal to effective LWW under regime condition)

Q - Design Discharge in Cum/sec

C - A constant taken as 4.80 for regime channels but it may vary from 4.50 to 6.30 according to local condition.

As per Cl.104.4 of IRC:5-1998 "If the river is of flashy nature and the bed does not submit readily to the scouring effect of the flood, the LWW should be determined by area-velocity method taking into account of design flood level and its water spread, the characteristics of bed material and the water surface slope (MFL slope)".

While deciding the linear water way the following points are to be considered.

1. Linear water way of the existing bridges located within 1.60km either on the U/S or D/S
2. 90% of the MFL spread at the site, immediate U/S and immediate D/S
3. Linear water way as required by PWD
4. Theoretical linear water way required as per design discharge
5. Linear water way of the railway bridge located within 1.60km either on the U/S or D/S

If a Railway bridge is located within 1.6 km from the proposed bridge site in the same river concurrence will have to be obtained for the LWW proposed from the Railways {vide Madras Highways Manual Vol-II, Part -II [Cl.10.2.6(b)]}

Once the Linear Water Way (LWW) is decided, suitable span and no. of spans may be decided depending upon the type of foundation. Longer spans (between

15m to 35m) and shorter spans (upto15m) may be preferred in case of deep foundation and shallow foundation respectively. In respect of open foundation economical span may be worked out, as below

Economical Span = 1.5x (Level of bottom of deck - foundation level)

8.14.4.5.6. SCOUR (Ref: Cl 703.2, IRC: 78)

Scour criteria plays vital role in deciding the depth of foundation. Similarly the silt factor plays vital role in deciding scour depth.

The mean scour depth below the MFL for natural channels flowing over scourable bed can be calculated theoretically from the following equation. (Cl.703.2, IRC:78, Ref.9)

Mean Scour Depth dsm = $1.34x[D_b^2/k_{sf}]^{1/3}$

D_b – The unit discharge in cumecs obtained by dividing the design discharge adopted for the foundation by theoretical LWW or actual effective LWW whichever is less (Cl.703.2.1, IRC:78). The effective LWW is to be calculated as per Cl.101.9 of IRC:5-1998

The design discharge is increased by certain percent as below to have adequate margin of safety and adopted for foundation design (Cl.703.1, IRC:78)

Table: 8.20

Catchment Area In sq.km	Increase over design Discharge In percentage
0-3000	30
3000-10000	30-20
10000-40000	20-10
Above 40000	10

The silt factor (k_{sf}) is to be ascertained for the representative sample of the bed materials obtained upto the maximum anticipated deepest scour (Cl.110.1.3 of IRC: 5)

k_{sf} - Silt factor = 1.76" d_m

d_m - weighted mean dia of the bed material up to anticipated deepest scour (mm)

The Value of k_{sf} can be taken from Cl.703.2.2.1 of IRC: 78 - 2000.

Type of bed material	dm	ksf
Coarse silt	0.04	0.35
Silt /fine sand	0.081 to 0.158	0.5 to 0.6
Medium sand	0.233 to 0.505	0.8 to 1.25
Coarse sand	0.725	1.5
Fine bajri and sand	0.988	1.75
Heavy sand	1.29 to 2.00	2.0 to 2.42

Typical method of determination of weighted mean diameter of particles (d_m):

Representative disturbed samples of bed materials shall be taken at every change of strata upto the maximum anticipated scour depth. The sampling should start from 300mm below the existing bed. About 500 g of each of the representative samples so collected shall be sieved by a set of standard sieves and the weight of soil retained in each sieve is taken. The results thereof are then tabulated. A typical test result is shown below (Table A & B)

TABLE A			
Sieve Designation	**Sieve Opening (mm)**	**Weight of soil retained**	**Percentage retained**
5.60mm	5.60	0	0
4.00mm	4.00	0	0
2.80mm	2.80	16.9	4.03
1.00mm	1.00	76.50	18.24
425 micron	0.425	79.20	18.88
180 micron	0.18	150.40	35.86
75 micron	0.075	41.00	9.78
Pan	55.40	13.21	
Total		**419.40**	

TABLE B			
Sieve No.	**Average size (mm)**	**Percentage Weight retained**	**Percent retained**
4.00 to 2.80 mm	3.40	4.03	13.70
2.80 to1.00mm	1.90	18.24	34.66
1.00mm to 425 micron	0.712	18.88	13.44
425 to 180 micron	0.302	35.86	10.83
180 to 75 micron	0.127	9.78	1.24
75 micron and below	0.0375	13.21	0.495
		Total	**74.365**

Weighted mean diameter d_m = 74.365/100

= 0.74365 say 0.74

For values of k_{sf} in respect of gravel and boulders with larger $d_{m,}$ Civil Engineering Hand Book by Khanna may be referred and judiciously decided. For Silt factor in respect of clay Appendix - 1 (page-63) of IRC: 78- 2000 may be referred and calculated accordingly, as below :

8.14.4.5.7. Guidelines for calculating silt factor for bed material consisting of clay.

In the absence of any formula 'k_{sf}' may be determined as per Clause 703.2.2 and adopted based on site information and behaviour history of any existing structure. The clayey bed having weighted diameter normally less than 0.04 offers more resistance to scour than sand though mean depth of scour as per the formula given in Cl.703.2 indicates more scour. In absence of any accepted rational formula or any data of scour at the site of the proposed bridge; the following theoretical calculation may be adopted.

1. In case of soil having $\phi < 15^0$ and c (cohesion of soil) > 0.2 kg / cm^2, 'k_{sf}' calculated as follows:

K_{sf} = F(1+ "c), where c is in kg/cm^2

where F = 1.50 for $\phi > 10^0$ and $< 15^0$

= 1.75 for $\phi > 5^0$ and $< 10^0$

= 2.00 for $\phi < 5^0$

2. Soils having $\phi > 15^0$ will be treated as sandy soil even if c is more than 0.2 kg cm^2 and silt factor will be as per provision of Cl.703.2.2

3. Bouldary Strata: (ref: Cl.9.3.2, IRC: SP: 13-2004) There is no rational methodtoassess scour in boulders or pebbles. In the absence of any formula k_{sf} may be determined as per clause 703.2.2 of IRC:78 and adopted. If say, average size of pebbles is d_b

Then, ksf = $1.76(d_b)^{1/2}$

for d_b = 50mm

ksf = $1.76(50)^{1/2}$ = 12.4

It is, however, better to investigate depth of foundations adopted in past for similar foundation and decide on the basis of precedence. Protection work around foundations in the form of curtain wall and apron of garland of blocks should be provided, when the foundation is laid on the bouldary strata.

In case of bridge mainly adopted as balancer, the mean depth 'd_{sm}' may be taken as (Highest Flood Level-Lowest Bed Level) divided by 1.27 (Cl 703.2.4 of IRC:78-2000)

8.14.4.5.8. Maximum depth of Scour for design of Foundation:

There are two different arrangement conditions in foundation viz

1. Foundation without bed protection,

2. Foundation with bed protection

8.14.4.5.8.1. Foundation without Bed Protection:

The maximum depth of scour below the MFL for the design of piers, abutments having individual foundation without floor / bed protection is taken as follows.

Flood without Seismic combination

Flood with Seismic combination

8.14.4.5.8.1.1. Flood without seismic combination:

1)	For piers	-	$2.0d_{sm}$
2)	For abutments	-	a) $1.27d_{sm}$ with approach retained or lowest bed level whichever is deeper b) 2.00 dsm with scour around (Cl.703.3 of IRC: 78 -2000)

Safe scour level for piers = MFL - ($2d_{sm}$ +2 metre)
Safe scour level for Abutments = MFL – ($1.27d_{sm}$ +2 metre)
(for approach retained condition)

For foundation without bed protection condition, open foundation, deep foundation such as pile foundation or well foundation are applicable. Open foundations are adopted usually for depth of foundation up to 4.5m from sill level. If there is no problem (such as sliding of soils during excavation) because of the presence of hard strata the depth of open foundation may be preferred even up to 5.0m from sill level. That is, the risk of sliding of soil during execution also governs the depth of open foundation, after satisfying scour criteria as well as SBC criteria.

8.14.4.5.8.1.2. Flood with seismic combination:

For load combination of Flood and Seismic loads (together with other appropriate combinations given elsewhere) the maximum depth of scour may be reduced by multiplying the factor of 0.9 to the scour depth arrived in case of flood without seismic combination.

8.14.4.5.8.2. Foundation with bed protection:

For raft foundation or open foundation with bed protection, the following values of maximum scour depth may be adopted

1) In a straight reach - $1.27d_{sm}$

2) In a bend - $1.50d_{sm}$ or on the basis of concentration of flow.

The length of apron in upstream may be 0.7 times of the same in downstream. (Cl.703.3.2 of IRC:78 - 2000)

If the river is of flashy nature and bed does not lend itself readily to the scouring effects of flood, the theoretical formula for d_{sm} and maximum depth of scour as recommended shall not apply. In such cases, the maximum scour depth shall be assessed from actual observations. (Cl.703.5 of IRC: 78 - 2000)

For foundation with bed protection condition, the bed protection level is taken as the maximum scour level. Therefore, Safe Scour level = Bed protection level - 2m.

8.14.4.6. When do we go for a foundation with bed protection?

The foundation with bed protection is preferred where adoption of shallow foundation becomes economical by restricting the scour.

For example, if a particular site though has good bearing strata at shallow depth but warrants a deep foundation as a result of calculated deep safe scour level, the cost of such bridge with deep foundation may not be financially viable. To restrict the cost, the foundation depth can be restricted to be shallow by providing a bed protection so as to arrest the scour at the level of bed protection.

The IRC: 78 - 2000 stipulates that the minimum depth of open foundation shall be upto a stratum having safe bearing capacity but not less than 2.0m below the scour level or the protected bed level. As such it is advisable to go for open foundation with bed protection which is economical than adopting pile or well foundation.

In case there is not adequate bearing capacity at shallow depth (even upto 3.0m depth) in the above example, but there is substantial increase in SPT (Standard Penetration Test) 'N' values beyond 3.0 m or so, but the 'N' values are not adequate enough to withstand the open foundation, then the possible foundation may be a raft foundation.

Foundation should be seated at safe scour level or below the safe scour level so that the foundation is protected against scour, provided adequate SBC is available at that level. That is any foundation level shall satisfy both scour criteria and SBC criteria as well.

If hard rock or soft rock is met with at a higher level than the safe scour level, the foundation can be seated on hard rock with an embedment of 0.6m into hard rock. In respect of soft rock the foundation is to be seated with an embedment of 1.50m into it. If SBC criteria is satisfied no foundation needs to be taken below the safe scour level in case of open foundation.

The rocky strata with ultimate crushing strength of 10 MPa is termed as hard rock. The rocky strata with ultimate crushing strength value between 2 MPa but less than 10 MPa is termed as soft rock.

The foundation level shall satisfy the SBC criteria also in addition to the scour depth criteria in respect of open foundation. The foundation level in respect of pile foundation shall satisfy scour depth criteria as well as pile capacity. The foundation level for well foundation shall satisfy scour depth criteria as well as the SBC criteria.

8.14.4.7. Design Of Bed Protection

For bridges where adoption of shallow foundation becomes economical by restricting the scour, floor / bed protection to bridges has to be provided. The bed protection will comprise of rigid flooring with curtain walls and flexible apron so as to check scour, washing away or disturbance by piping action, etc.

Usually performance of similar existing works is the best guide for finalizing the design of new works. However, the following minimum specification for floor protection shall at least be followed while designing new structures subject to the general stipulation that post protection works velocity under the structure does not exceed 2 m/sec and the intensity of discharge is limited to $3m^3$/sec (Cl. 10.1, IRC:89-1997, Ref: 17)

The bed protection involves the provision of rigid apron, curtain wall and flexible apron on U/S & D/S of the proposed bridge. While designing the bed protection, the following criteria shall be adopted. (Ref:IRC:89-1997, Cl. 10.2)

1. The top of bed protection shall be kept at sill level or 300mm below lowest bed level.

2. The rigid flooring shall be provided under the bridge and it shall extend for a distance of at least 3 m on U/S & 5m on D/S of the bridge.

3. The rigid flooring shall consist of 150mm thick flat stone / bricks on edge in cement mortar 1:3 laid over 300mm thick cement concrete M-15 grade laid over a layer of 150mm thick cement concrete M-10 grade (Joints at suitable spacing (say 20m) may be provided).

4. **Curtain walls:** The rigid flooring shall be enclosed by curtain wall (tied to the wing wall) with a minimum depth of 2m below floor level on upstream side and 2.5m on downstream side. The curtain wall shall be in cement concrete M-10 grade / brick / stone masonry in cement mortar 1:3. The rigid flooring shall be continued over the top width of curtain walls.

5. Flexible apron 1m thick comprising loose stone boulders (weighing not less than 40kg) shall be provided beyond the curtain walls for a minimum distance of 3m on upstream side and 6m on downstream side. Where required size stones are not economically available, cement concrete blocks of stones in wire crates may be used in place of isolated stones.

6. Wherever scour is restricted by provision of flooring / flexible apron, the work of flooring / apron etc., should be simultaneously completed along with the work on foundations so that the foundation work completed and left to itself is not endangered.

The following formulae are generally adopted for the rivers in Tamil Nadu in the design of the components of the bed protection.

1. Dept1h of Curtain wall:
   d_{sm} - (MFL - Sill)

2. Width of flexible apron on U/S:
   1.5 [(1.5 d_{sm} - depth of flow or (MFL - Sill))]

3. Width of flexible apron in D/S:
   1.5 [2d_{sm} - depth of flow]

Thus, foundation depth for foundation with bed protection condition shall not be less than 2m below the level of bed protection (Cl. 705.2.1 of IRC: 78 - 2000) provided the velocity does not exceed 2m/sec and unit discharge does not exceed 3 cum/sec (vide Cl.10.1 of IRC: 89 - 1997)

The raft foundation involves the provision of RCC / CC raft slabs laid over compacted clear river sand up to the level of 3.0m depth and this entire arrangement is encased by cut-off wall alround. The max. depth of raft foundation generally adopted is 3.0 m from sill level.

8.14.4.8. DEPTH OF BRIDGE FOUNDATIONS

The following rules shall be followed while fixing the depth of bridge foundations:

Rule (1) Erodible Beds. The foundations shall be taken down to a depth below the maximum high flood level one-third greater than the calculated depth of maximum scour subject to a minimum depth below the scour line of two metres for arched bridges, and 1.2 metres for other bridges.

Rule (2) Hard Beds, When a substantial stratum of solid rock or other material not erodible able the calculated maximum velocity is encountered at a level higher than or below that given by Rule (1) above, the foundations shall be securely anchored into that material.

Rule (3) AH Beds. The pressure on the foundation material must be well within the bearing capacity of the material.

These rules enable us to fix the level of the foundations of abutments and piers.

The rules mentioned in the last para apply when no bed floor is provided under the structure and the stream is free to scour as it may. The structure is then said to have deep foundations. It is sound to design deep foundations as far as circumstances permit.

In the case of small culverts, however, bed floors may be provided. In this connection the following is considered sound practice for culverts on erodible soil:

Keep the top of the floor about 0.3 metre below the bed level. Take the foundations of the abutment 1.25 metres below the .'top of the floor. Provide an upstream curtain wall 1 to 1.50 metres deep and a downstream curtain wall 1.5 to 2.5 metres deep from the top of the floor. The precise depth of curtain walls, within the stated limits, will depend on the velocity of flow through the structure and erodibility of theibed materials..

This rule may be followed when it is intended to avoid calculation of maximum scour depths for want of sufficient site data.

8.14.5. Type Of Foundations.

The subsoil characteristics obtained at a particular site and consequently the type of foundations feasible in selection of type of structure and span arrangement as already mentioned.

Table: 8.21. Maximum Safe Bearing Capacity of Soils

1.	Hard rock (Granite , trap)	330 Tonne/m^2
2.	Laminated rock (Sand stone and lime stone)	165 Tonne/m^2
3.	Soft rock	45 Tonne / m^2
4.	Gravel, Sand gravel compact and offering high resistance	45 Tonne / m^2
5.	Coarse sand, compact and dry	45 Tonne/ m^2
6.	Medium sand, compact and dry	25 Tonne / m^2
7.	Fine sand, silt (dry lumps easily pulversied finger)	15 Tonne/ m^2
8.	Loose gravel or sand gravel mixture, dry	25 Tonne/ m^2
9.	Fine sand, loose and dry	10 Tonne/ m^2
10.	Soft shale, hard or stiff clay in deep bed dry	45 Tonne/ m^2
11.	Medium clay readily intended with a thumb nail	25 Tonne / m^2
12.	Moist clay and sand clay mixture which can be intended with strong thumb pressure	15 Tonne/ m^2
13.	Soft dry intended with moderate thumb pressure	10 Tonne/ m^2
14.	Very soft day which can be pentrated several centimeters with the thumb.	5 Tonne / m^2

i) Shallow foundations:

Isolated open foundations are feasible where an SBC of about 15 t/m^2 or more is available at shallow depths with in-erodible substratum. Here again, open excavation is feasible only upto a depth of 3 to 4m where the subsoil is porous and water table is high. In cases,, where the SBC is still less and where smaller spans are economical from other considerations, raft foundations or box structures with floor protection and curtain walls are thhe other options

ii) Deep foundations :

where suitable founding strata is available at a depth of 6 metres or more substantial depth of standing water, highly pervious substratum and large scour depth, it may be advisable to go for deep foundation like (a) well, or (b) piles.

a) Well foundations :

This is one of the most popular types of deep foundations prevalent in our country, due to various reasons like its simplicity, requirement of very little equipments for its execution, adaptability to different subsoil conditions are Caissons are an adaptation of well foundations.

b) Pile foundation:

Pile foundations are another type of deep foundations which are suited for adoption in the following situations:

Availability of good founding strata below large depth of soft soil. Very deep foundations beyond the limit of pneumatic operations usually at a depth beyond 35 metres or so. In some cases of strata underlying deep standing water and the strata being very hard not permitting easy sinking of wells or based on economic factors deciding the use of piles as compared to wells. However, pile foundations are not preferred within the flood zone of the river with deep scour.

Classification of piles

1. Precast driven piles
2. Driven cast - in - situ piles
3. Bored cast-in-situ piles

4. Bored precast piles and
5. Driven steel piles

8.14.6. SPAN ARRANGEMENTS

The ranges of span length within which a particular type of superstructure can be economical along with other considerations like type of foundation etc. are given below: (Ref: Cl.5.7.7 of IRC: SP: 54-2000)

Table: 8.22

Sl. No.	Type of Superstructure	Span length (m)
1)	RCC single or multiple boxes	1.5 to 15
2)	Simply supported RCC slabs	3 to 10
3)	Simply supported RCC T - Beam	10 to 25
4)	Simply supported PSC Girder bridges	25 to 45
5)	Simply supported RCC voided slabs	10 to 15
6)	Continuous RCC voided slabs	10 to 20
7)	Continuous PSC voided slabs	15 to 30
8)	RCC box sections; simply supported / balanced cantilever continuous	25 to 50
9)	PSC box sections; simply supported / balanced cantilever	35 to 75 m
10)	PSC cantilever construction / continuous	75 to 150 m
11)	Cable stayed bridges	200 to 500 m
12)	Suspension bridges	500m onwards

The above ranges of span length are given as general guidelines only. However, the choices of a particular span arrangement and type of structure depends upon several factors such as

Site characteristics

Type of subsoil strata

Height and length of the bridge

Design and construction aspects

Construction technology and time frame of construction etc.

8.14.7.Afflux :

Afflux is the height by which the natural flood level of the river rises at any point due to constriction and or obstruction. It has to be estimated not only for its effect on the design of the bridge, but also to ensure that it may not affect condition on the upstream side of the bridge. The type of bed and bank material and the type of bridge influences the extent of afflux. Constriction of channel on account of flood banks, guide bunds, piers, floor protection etc., increase afflux. Afflux is high in flashy rivers as well. Afflux may be calculated approximately using Molesworth formula as given below:

$$h = (V^2/17.8+0.015)\left((A/a)^2 - 1\right)$$

where,

h = afflux in metre

V = average velocity of water in the river prior to constriction in m/sec.

A = Unobstructed sectional area of the river at proposed site in sq.m

a = Constricted area of the river at the bridge in sq.m

For guidance IRC special publication No.13 may be referred to for calculation of afflux.

8.14.8. CLEARANCE

a. Vertical clearance above H.F.L.,

i) The vertical shall ordinarily be adopted as given in table: 8.22. below.

Table: 8.23

Discharge in cumecs	Minimum vertical Clearances in mm
Upto 0.3	150
Above 0.3 and upto 3	450
Above 3 and upto 30	600
Above 30 and upto 300	900
Above 300 and upto 3000	1200
Above 3O00	1500

ii) For high level bridges having flat soffit or soffit with a very flat curve, the minimum vertical clearance to be provided above affluxed HFL shall normally be as above

Note:

The minimum clearance shall be measured from the lowest point of the deck structure inclusive of main girder in the central half of the clear opening unless otherwise specified.

iii) Vertical clearance may be increased based on navigational requirements or where the chances of having floating debris like trees are high.

iv) For arched openings of high level bridges having overhead decking, the clearance below the crown of the intrados of arch shall not be less than one tenth of the maximum depth of water plus one third of the rise of the arch intrados.

v) In bridges provided with metallic bearings, no part of the bearing shall be less than 500 mm above the affluxed HFL.

vi) Difference between deck level and affluxed HFL shall not be less than 1.75 m to safeguard road crust in approach embankment against capillary action of water.

8.14.8.1. Clearance for traffic :

i). For footways and cycle tracks, the minimum vertical clearance shall be 2.25 metres.

ii). For vertical and horizontal clearances at under passes and / rail over bridges the essential provisions are given below.

a. Lateral clearance at under passes desirably the full roadway width of the approaches should be carried through the under pass.

b. Vertical clearance at under passes

Rural areas - 5m min

Urban areas - 5.5 m min

8.14.9. CARRIAGE WAY

Bridges are generally designed with two lane Carriage way of 7.50 m width in between kerbs considering the possible upgradation of classification of the road, possible growth of traffic due to economic development and the design life of the structure. It is not desirable and advisable to provide a single lane bridge to be adequate unless otherwise it is specifically decided so by the authorities.

The clear width of carriageway between kerbs for various categories of bridge shall be as follows (Cl.4.6.1.1 of MORTH & pocket book for Bridge Engineers, (Ref:2)

Single lane bridge - 4.25 m (i.e 3.75 + 2 x 0.25m)

Two lane bridge - 7.50 m (i.e 7.00 + 2 x 0.25m)

Multiple lane bridge - 3.5 m per lane plus 0.5 m for each carriage way

(The shyness clearance of 0.25m on either side of carriageway)

Road Bridge shall provide for either one lane or two lane or multiple of two lanes. Three lane bridge shall not be constructed.

Intermediate lane of 5.50 m in between kerbs may also be constructed provided adequacy of lane width is justified with reference to traffic data and other factors.

8.14.9.1. PROVISION OF FOOTPATH

In Urban areas, footpath of a minimum width of 1.5m may be provided in all bridges. In Rural areas also bridges may preferably be provided with footpath if there is habitation or possibility of development of industrial growth or habitation in future within a distance of 1 km, in view of the possible growth of pedestrian traffic, particularly when such a facility cannot be added to at a later date.

In case of divided carriageways, footpath shall be provided only on left side of the carriage way for each direction of traffic.

Provision of footpath for bridges in rural areas particularly for long bridges shall be considered in case to case basis.

In case of very high volume of pedestrian traffic, the provision of footpath of more than 1.5m width (Cl.112.5 IRC:5 - 1998, Cl.6.2.5 of IRC 86 - 1983) or a separate pedestrian bridge may be considered depending on site condition.

8.14.9.2. PROVISION OF CRASH BARRIER AND HAND RAILS

RCC crash barriers (M40) may be provided for all bridges in Highway to safeguard against errant vehicles. (IRC: 21 - 2000)

Where footpath is provided, the crash barrier shall be so located as to separate main carriage way from footpath for the safety of pedestrian. The pedestrian hand rail shall be provided at the edge of the superstructure.

Where footpath is not provided, RCC crash barrier shall be provided with safety kerb of 750mm width (Cl.111.3 of IRC:5 - 1998) at the edge of superstructure to safeguard against errant vehicles.

The type design for the crash barrier may be adopted as per IRC 5 - 1998. Circular openings of 70mm in diameter may be provided in a staggered manner in the crash barrier so as to relieve the pressure due to wind or extraordinary flow and also to drain the surface flow on foot path.

Reinforcements in crash barriers shall be modified so as to accommodate the circular holes. The adequacy of reinforcement in the kerb, footpath and hand rails and posts may be ensured.

c. Vertical clearance for railway traction (broad gauge)

Electric traction - 5.87 m min

Non-electric traction - 4.875 m min

d. Vertical clearance for power/ telecommunication lines

Lines carrying low voltage upto 110 v - 5.5 m min

Electric power lines upto 650 v - 6.0 m min.

Electric power lines > 650 v - 6.5 m min

8.14.10. Construction Joints

Location

The following considerations shall be taken into account for their location :

(i) Joints shall be provided in non-aggressive zones or in non-splash zones.If not feasible, the joints shall be sealed.

(ii) Joints should be positioned where they are readily accessible for preparation and concreting, such as location where the cross section is relatively small, and where reinforcement is not congested.

(iii) In beams and slabs, joints should not be near the supports. Construction joints between slabs and ribs in composite beams should be avoided.

(v) Location of joints shall minimise the effects of the discontinuity on the durability, structural integrity and the appearance of the structure.

Preparation of Surface of the Joint

Laitance shall be removed before fresh concrete is cast. The surface shall be roughened. Care shall be taken that they should not dislodge the coarse aggregates. Concrete may be brushed with a stiff brush soon after casting while the concrete is still fresh.

If the concrete has partially hardened, it shall be treated by wire brushing or with a stiff water jet followed by drying with air jet immediately.

Fully hardened concrete shall be treated with mechanical hand tools or grit blasting, taking care not to split or crack aggregate particles.

Before further concrete is cast, the surface should be thoroughly cleaned to remove debris and accumulated rubbish, one effective method being by air jet.

Where there is likely to be a delay before placing the next concrete lift, protruding reinforcement shall be protected. Before the next lift is placed, rust, loose mortar or other contamination shall be removed from the reinforcements. In aggressive environment, the concrete shall be cut back to expose the reinforcements for a length of about 50 mm to ensure that contaminated concrete is removed.

The joints surface not be contaminated with release agents, dust or curing membrance.

Concreting of Joints

The old surface shall be thoroughly cleaned and soaked with water. Standing water shall be removed shortly before the new concrete is placed and the new concrete shall be thoroughly compacted. Concreting shall be carried out continuosly upto the construction joints.

Surface retarders may be used to improve the quality of construction joints.

For a vertical construction joint, a stopping board shall be fixed previously at the predetermined position and shall be properly stayed to prevent its displacement or bulging when concrete is compacted against it. Concreting shall be continued right upto the board.

8.14.11. Protection Work

The floor protection should be properly designed as per the detailed guidelines contained in IRC: 89.However the minimum specifications for floor protection are given below for guidance.These may be adopted in the absence of any other more rigorous requirements / rational design.

(i) The post construction velocity under the structure should not exceed 2 m/sec and the intensity of discharge is limited to $3m^3$/sec... except in the case of properly designed raft foundation with adequate protective works.

(ii) The rigid flooring under the structure should extend for a distance of atleast 3m on upstream side and 5m on downstream side of the structure. However if splayed wing walls are provided, the flooring should extend upto the line connecting the end of the wing walls on either side of the structure. In case of well designed raft foundation with upstream and downstream cut-off walls, the depth of cut-off walls and length of flooring (apron)could be suitably changed depending on the successful practice followed inthe State.

(iii) The top of the flooring should be kept 300mm below the lowest bed level to prevent the flooring from acting as a weir when retrogression of levels take place.

(iv) The rigid flooring shall consist of 150mm thick flat stone/bricks on edge in cement mortar 1:3 laid over 300 mm thick cement concrete M15 grade over a layer of 150 mm thick cement concrete M1O. In case of streams carrying abrasive particles with velocities higher than 4m/sec., an alternative specification of flooring comprising of 450mm thick concrete layer in M20 over 150mm thick concrete layer in M15 grade can be adopted. Spacing of the joints should be limited to about 20m.

(v) The rigid flooring should be enclosed by cut-off/curtain walls (tied to the wing walls) with a minimum depth below floor level of 2m on upstream side and 2.5m on down stream side. The cut-off/curtain walls should be in cement concrete M15 grade/brick/ stone masonry in cement mortar 1:3.The rigid flooring shall be continued over the top width of the cut-off / curtain walls. Horizontal/ vertical joints in curtain/cut-offwalls should be avoided.

(vi) Flexible apron 1m thick comprising of loose stone boulders (weighing not less than 40 kg) should be provided beyond the curtain/cut-off walls The length of apron on the down stream side should be adequate to launch upto the designed maximum scour level in a slope of 2 horizontal to 1 vertical and the length of apron on the upstream should not be less than about 0.7 times of the same on downstream side subject to a minimum length of 4m on upstream side and 6m on downstream side. In case required size of stones are not economically available, stones in wire crates or cement concrete blocks may be used inplace of specified stones.

(vii) Crated boulder aprons should also be preferred at sites near inhabited areas so as to discourage removal of stones by anti-social and unscrupulous elements.

(viii) It is essential that the work of bed protection is simultaneously completed along with the work on the foundations of the structure to prevent any damage to the foundations.

The types of river training and protective works generally being used are as follows:

(i) Guide bunds

(ii) Spurs or groynes

(iii) River bank protection

(iv) Approach road protection

(v) River bed protection

The special features alongwith the broad design principales for each type are described in IRC:89-1987.

8.14.12. Worked out Example

DISCHARGE CALCULATION BY AREA- VELOCITY METHOD

Name of the work : Construction/ Reconstruction of a bridge across…………..... river at km ….…. of …………………………….. road

Various cross-sections of the stream is calculated by area - velocity method using the formula

Q = A x C x sqrt (R x S) where

S = Bed slope of the stream

R = Hydraulic mean depth given by R = A/P

A = Area of the cross-section

P = Wetted perimeter of the stream

C = Kutter's constant which is given by

$$C = \frac{23+(0.00155/S)+(1/N)}{1+(23+0.00155/S)*(N /\mathrm{sqrt}(R))}$$

N = Coefficient of rougosity which depends on the roughness of the stream (see Table: 8.18)

CROSS SECTION AT 500 U / S (Name of Channel)

MFL	BED LEVEL	LEVEL DIFF	TWICE DIFF	DIS "X"	TWICE AREA	VERTI CAL DIFF"Y"	Wetted Perimeter P = SQRT (X^2+Y^2)
113.32	113.320						
	110.315	3.005	3.005	3.600	10.818	3.005	4.689
	109.765	3.555	6.560	9.000	59.040	0.550	9.017
	109.655	3.665	7.220	10.000	72.200	0.110	10.001
	109.745	3.575	7.240	10.000	72.400	-0.090	10.000
	109.945	3.375	6.950	9.000	62.550	-0.200	9.002
	110.375	2.945	6.320	6.000	37.920	-0.430	6.015
	111.655	1.665	4.610	5.000	23.050	-1.280	5.161
	112.835	0.485	2.150	1.000	2.150	-1.180	1.547
	113.320	0.000	0.485	0.600	0.291	-0.485	0.772
					340.419		56.204

A = 170.210 $m^{2,}$ P = 56.205 m, N = 0.04, S= 0.000414

R = 170.21/56.205= 3.029 m

$$C = \frac{23+(0.00155/0.000414)+(1/0.04)}{1+(23+0.00155/0.000414)*(0.04/SQRT(3.029))}$$

= 32.047

Velocity = 32.047*sqrt(0.000414*3.029)

= 1.135 m/sec

Discharge = 1.135*170.21

= 193.189 cum/sec

CROSS SECTION AT 500 D / S (Name of Channel)

MFL	BED LEVEL	LEVEL DIFF	TWICE DIFF	DIS "X"	TWICE AREA	VERTI CAL DIFF"Y"	Wetted Perimeter P = SQRT (X^2+Y^2)
113.3	113.300						
	109.875	3.425	3.425	6.600	22.605	3.425	7.436
	109.425	3.875	7.300	7.000	51.100	0.450	7.014
	109.335	3.965	7.840	10.000	78.400	0.090	10.000
	109.305	3.995	7.960	10.000	79.600	0.030	10.000
	111.435	1.865	5.860	5.000	29.300	-2.130	5.435
	111.735	1.565	3.430	2.000	6.860	-0.300	2.022
	112.735	0.565	2.130	11.000	23.430	-1.000	11.045
	113.300	0.000	0.565	1.700	0.961	-0.565	1.791
					292.256		54.745

Velocity = 31.272*sqrt(0.000414*2.67)

= 1.04 m/sec

Discharge = 1.04*146.128

= 151.974 cum/sec

Summary of discharges by A.V method:

Sl.No.	Cross section @	Velocity in m/sec	Discharge in m^3/sec
1	600m U/S	1.135	193.189
2	400m U/S	1.16	——-
3	300m U/S	1.00	——-
4	200m U/S	1.04	——-
5	100m U/S	1.04	——-
6	At Site	1.00	——-
7	100m D/S	1.10	——-
8	200m D/S	1.10	——-
9	300m D/S	1.05	——-
10	400m D/S	0.99	——-
11	500m D/S	1.04	151.974

Let the Average Discharge be =157.928, Average discharge +10% = 173.721, Average Discharge -10% = 142.135

Maximum discharge within the Range of ± 10% variation from the Average discharge is to be taken as the **discharge by the Area Velocity Method**

Max discharge between the Range of ±10%, i.e in between 142.135 and 173.721

Therefore discharge by A.V Method (i) = 167.392 m^3/sec or 168 m^3/sec

Velocity corresponding to this discharge = 168/ area of flow at site,

velocity = 168/159.69 = 1.052 m/sec

Max. discharge furnished by P.W.D(ii) = 37.9 m^3/sec

The maximum discharge among (i) & (ii) is to be taken as the design discharge = 168 m^3/sec, Design velocity = 1.052 m / sec

LINEAR WATERWAY CALCULATION

MFL @ Site	= **RL 113.130**
Proposed sill level	= **RL 109.540** (average)
Design discharge D	= 168 m^3/sec
Design velocity	= 1.052 m/sec
Afflux assumed h_a	= 0.15 m
Depth of flow d	= MFL - Sill LVL = RL 113.130 - RL 109.540
	= 3.590 m
Velocity of approach V_a	= $(v \times d) / (d+h_a)$
	= (1.052x3.59) / (3.59+0.15)
	= 1.01 m/sec
Head due to velocity	
of approach H	= $Va^2/2g$
	= 1.01x1.01/(2x9.81)
	= 0.052 m
Head causing the flow h	= $H + h_a$
	= 0.052+0.15
	= 0.202 m
Velocity through vent v_v	= sqrt(2gh)
	= sqrt(2x9.81x0.202)
	= 1.99 m/sec
Linear water way required L_{ww}	= $D/ (0.9 \times d \times V_v)$
	= 168/(0.9x3.59x1.99)
Linear water way	
required L_{ww}	= **26.20 m**

SCOUR DEPTH CALCULATION

Design discharge = **168 m^3/sec**

Design Velocity = **1.052 m/sec**

M.F.L = **RL 113.130**

Sill level = **RL 109.540**

Silt factor for representative

sample = **1.218**

Linear water way provided = **26.20 m**

The mean depth of scour d_{sm} shall be calculated below the M.F.L. as per the provision of cl.703.2.2.1.of IRC-78-2000

Mean scour depth d_{sm} = $1.34\ (D_b^{\,2} / K_{sf})^{1/3}$

where D_b is the discharge in cumecs per unit width and K_{sf} is the silt factor for a representative sample of the bed material.

As per cl.703.1 of IRC-78-2000, design discharge is increased 30 %

Total discharge = 168 (1+0.3) = 218.4 m^3/sec

Discharge per m width = 218.4/ 26.20

= 8.336 m^3/sec

Normal scour depth d_{sm} = $1.34\ (8.336*8.336/1.218)^{1/3}$

d_{sm} = 5.159m

Max. scour depth @ abutment = 1.27 d_{sm}

= 6.552m

Max. scour depth @ pier = 2 d_{sm}

= 10.318m

As per the provisions under cl.705.2.1 of IRC 78-2000, the minimum depth of open foundation shall be upto the stratum having a safe bearing capacity of but not less than 2.0 m below the scour level or from the protected bed level

FOUNDATION WITHOUT BED PROTECTION

		Abutment	**Pier**
Max. scour depth	=	6.552m	10.318m
Max. scour level from MFL	=	113.13-6.552	113.13-10.318
		RL 106.578	RL 102.812
Safe foundation level	=	106.578-2	102.812-2
(Max. scour level - 2m)	=	**RL104.578**	**RL 100.812**
Depth of foundation below sill	=	109.54-104.578	109.54-100.812
(Sill level - Foundation level)	=	**4.962m**	**8.728m**

FOUNDATION WITH BED PROTECTION

Safe foundation level for abutment & pier = Sill level -2m

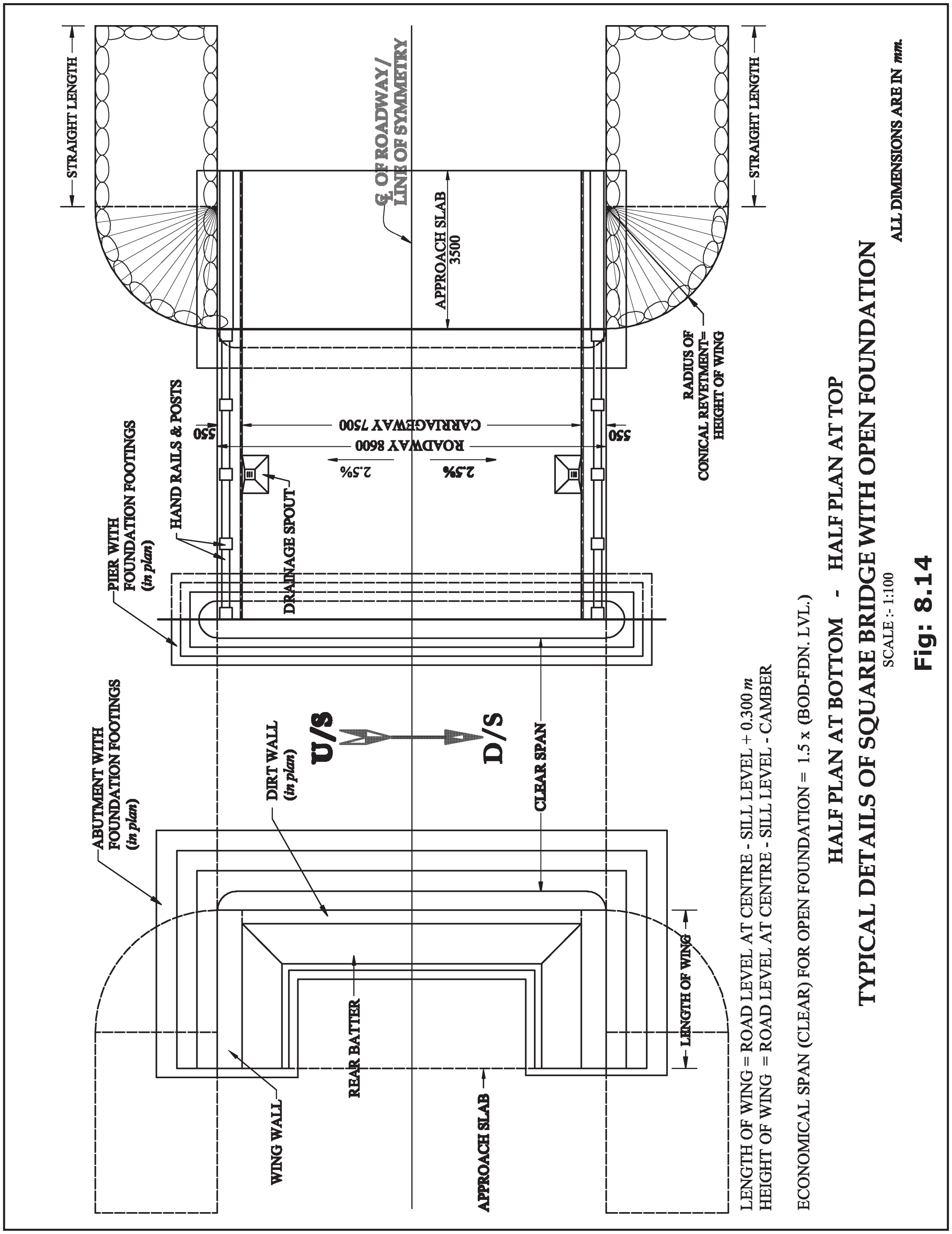
= 109.54-2

= RL 107.540

Discharge per m width = 8.336 m^3/sec **>** 3 m^3/sec

Velocity = 1.052 m / sec **<** 2 m / sec

Foundation with bed protection is not possible



HALF PLAN AT BOTTOM - HALF PLAN AT TOP

TYPICAL DETAILS OF SQUARE BRIDGE WITH OPEN FOUNDATION

SCALE :- 1:100

Fig: 8.14

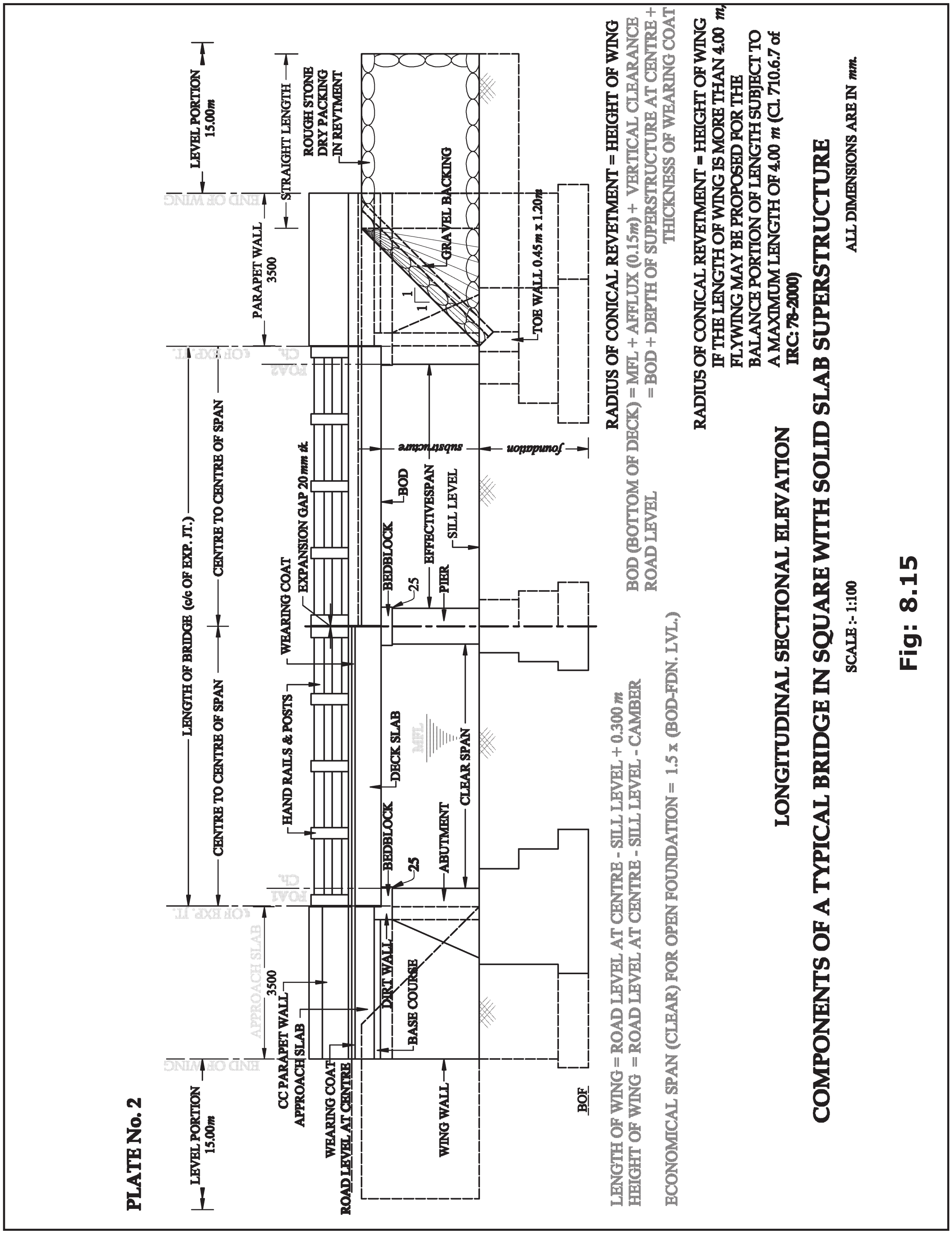


PLATE No. 2
LEVEL PORTION 15.00m
END OF WING
CC PARAPET WALL
APPROACH SLAB
WEARING COAT
ROAD LEVEL AT CENTRE
WING WALL
APPROACH SLAB
3500
DIRT WALL
BASE COURSE
BOF
c/c OF EXP. JT.
ROAD C/L
BEDBLOCK
25
ABUTMENT
CENTRE TO CENTRE OF SPAN
HAND RAILS & POSTS
DECK SLAB
CLEAR SPAN
MFL
LENGTH OF BRIDGE (c/c OF EXP. JT.)
WEARING COAT
EXPANSION GAP 20 mm tk.
BEDBLOCK
25
PIER
EFFECTIVE SPAN
SILL LEVEL
BOD
CENTRE TO CENTRE OF SPAN
substructure
foundation
PARAPET WALL 3500
STRAIGHT LENGTH
ROUGH STONE DRY PACKING IN REVTMENT
GRAVEL BACKING
1
1
TOE WALL 0.45 m x 1.20 m
LEVEL PORTION 15.00m
LENGTH OF WING = ROAD LEVEL AT CENTRE - SILL LEVEL + 0.300 m
HEIGHT OF WING = ROAD LEVEL AT CENTRE - SILL LEVEL - CAMBER
ECONOMICAL SPAN (CLEAR) FOR OPEN FOUNDATION = 1.5 x (BOD-FDN. LVL.)
RADIUS OF CONICAL REVETMENT = HEIGHT OF WING
BOD (BOTTOM OF DECK) = MFL + AFFLUX (0.15m) + VERTICAL CLEARANCE
= BOD + DEPTH OF SUPERSTRUCTURE AT CENTRE + THICKNESS OF WEARING COAT
ROAD LEVEL
RADIUS OF CONICAL REVETMENT = HEIGHT OF WING
IF THE LENGTH OF WING IS MORE THAN 4.00 m, FLYWING MAY BE PROPOSED FOR THE BALANCE PORTION OF LENGTH SUBJECT TO A MAXIMUM LENGTH OF 4.00 m (Cl. 710.6.7 of IRC: 78-2000)
LONGITUDINAL SECTIONAL ELEVATION
COMPONENTS OF A TYPICAL BRIDGE IN SQUARE WITH SOLID SLAB SUPERSTRUCTURE
SCALE :- 1:100
ALL DIMENSIONS ARE IN mm.

Fig: 8.15

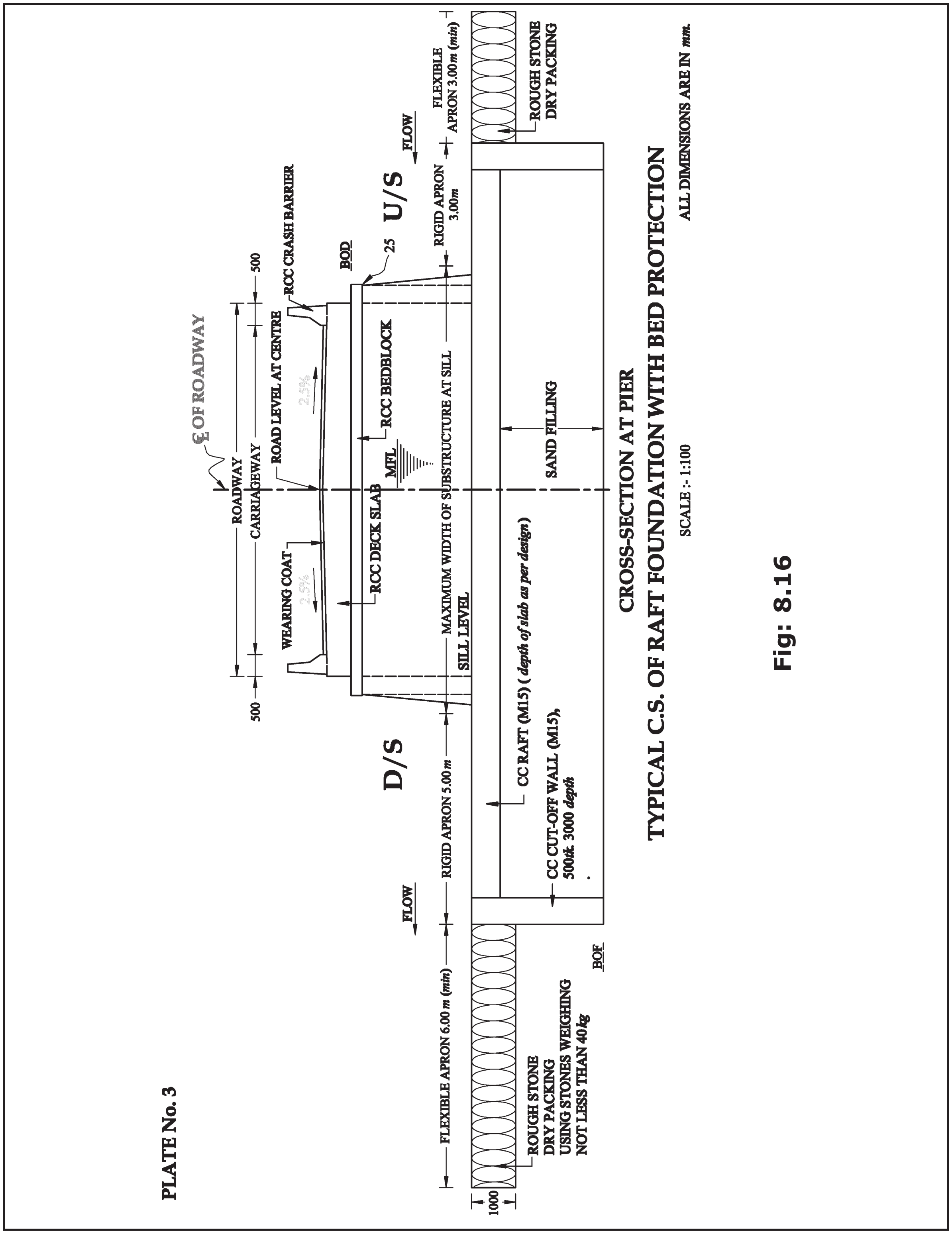


PLATE No. 3
TYPICAL C.S. OF RAFT FOUNDATION WITH BED PROTECTION
CROSS-SECTION AT PIER
SCALE :- 1:100
ALL DIMENSIONS ARE IN mm.
℄ OF ROADWAY
ROADWAY
CARRIAGEWAY
500
500
RCC CRASH BARRIER
ROAD LEVEL AT CENTRE
WEARING COAT
2.5%
2.5%
RCC DECK SLAB
RCC BEDBLOCK
BOD
25
MFL
MAXIMUM WIDTH OF SUBSTRUCTURE AT SILL
SILL LEVEL
SAND FILLING
CC RAFT (M15) (depth of slab as per design)
CC CUT-OFF WALL (M15), 500thk. 3000 depth
D/S
U/S
FLOW
FLOW
RIGID APRON 5.00 m
RIGID APRON 3.00m
FLEXIBLE APRON 6.00 m (min)
FLEXIBLE APRON 3.00 m (min)
ROUGH STONE DRY PACKING USING STONES WEIGHING NOT LESS THAN 40 kg
ROUGH STONE DRY PACKING
BOF
1000

Fig: 8.16

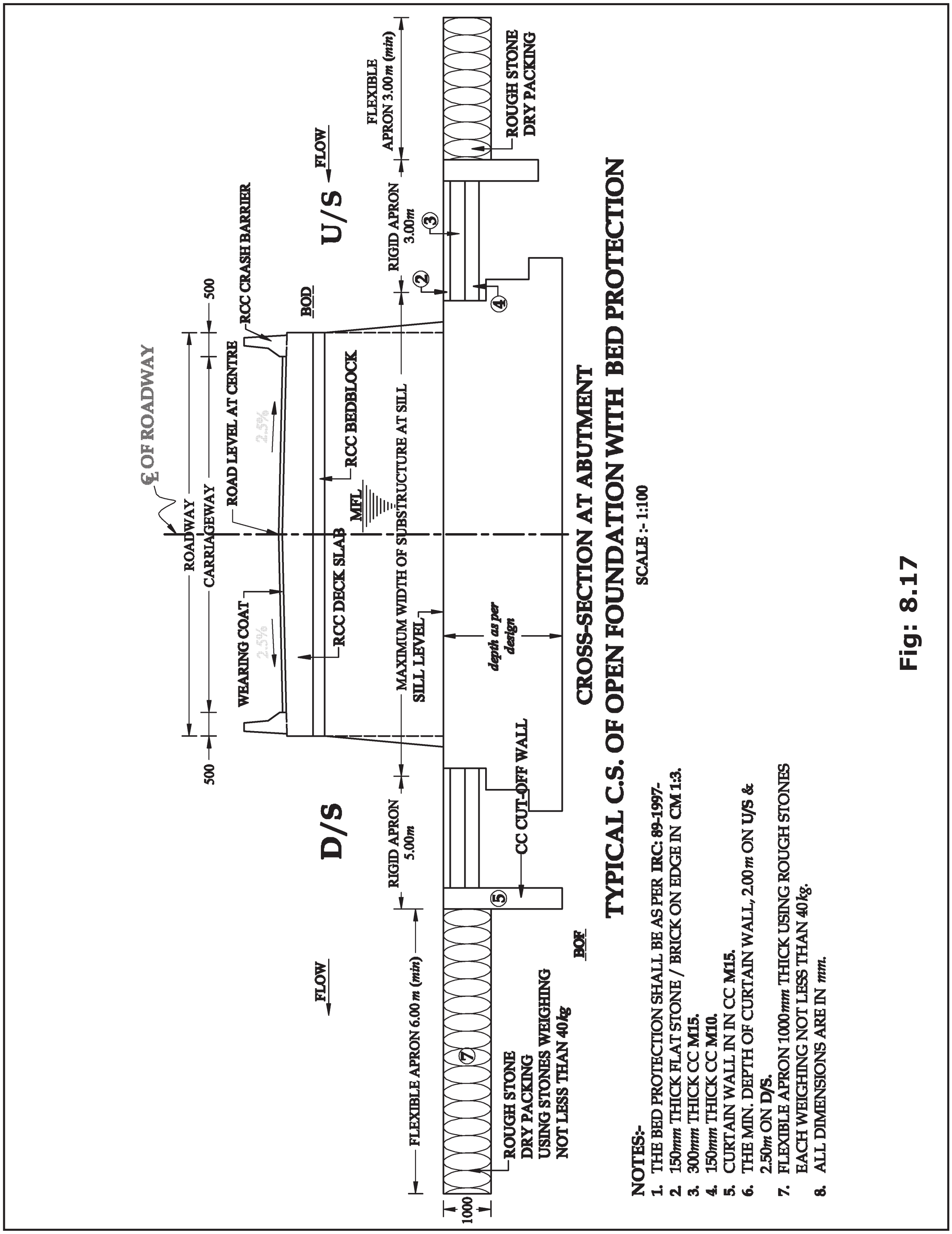
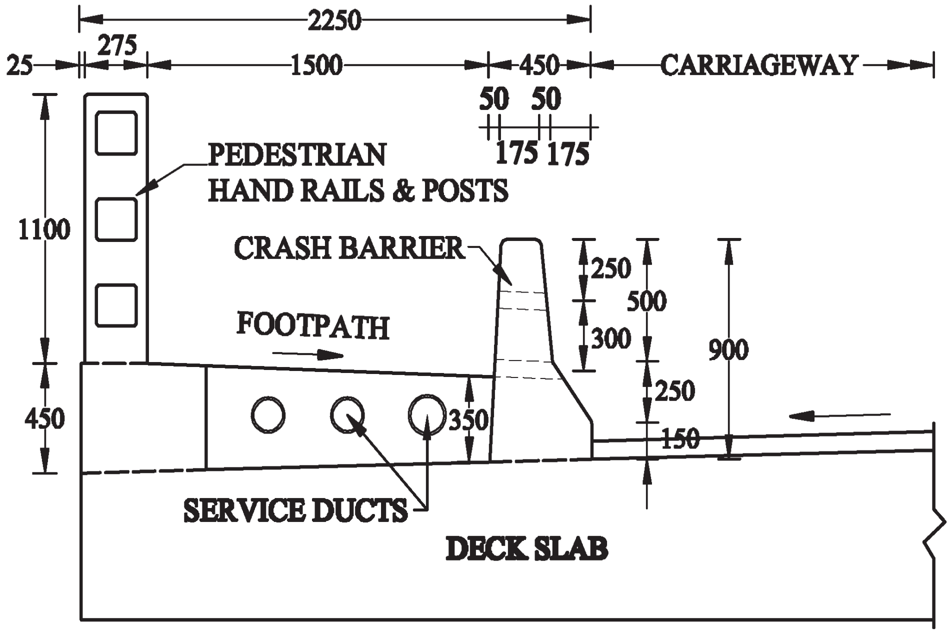

CROSS-SECTION AT ABUTMENT
TYPICAL C.S. OF OPEN FOUNDATION WITH BED PROTECTION
SCALE :- 1:100
℄ OF ROADWAY
ROADWAY
CARRIAGEWAY
500
500
ROAD LEVEL AT CENTRE
RCC CRASH BARRIER
WEARING COAT
2.5%
2.5%
RCC DECK SLAB
RCC BEDBLOCK
MFL
BOD
BOF
MAXIMUM WIDTH OF SUBSTRUCTURE AT SILL
SILL LEVEL
depth as per design
U/S
D/S
FLOW
FLOW
RIGID APRON 3.00m
RIGID APRON 5.00m
FLEXIBLE APRON 3.00m (min)
FLEXIBLE APRON 6.00 m (min)
ROUGH STONE DRY PACKING
ROUGH STONE DRY PACKING USING STONES WEIGHING NOT LESS THAN 40kg
CC CUT-OFF WALL
1000
NOTES:-
1. THE BED PROTECTION SHALL BE AS PER IRC: 89-1997-
2. 150mm THICK FLAT STONE / BRICK ON EDGE IN CM 1:3.
3. 300mm THICK CC M15.
4. 150mm THICK CC M10.
5. CURTAIN WALL IN IN CC M15.
6. THE MIN. DEPTH OF CURTAIN WALL, 2.00m ON U/S & 2.50m ON D/S.
7. FLEXIBLE APRON 1000mm THICK USING ROUGH STONES EACH WEIGHING NOT LESS THAN 40kg.
8. ALL DIMENSIONS ARE IN mm.

Fig: 8.17

TYPICAL SPECIFICATIONS
(for Moderate Exposure):-

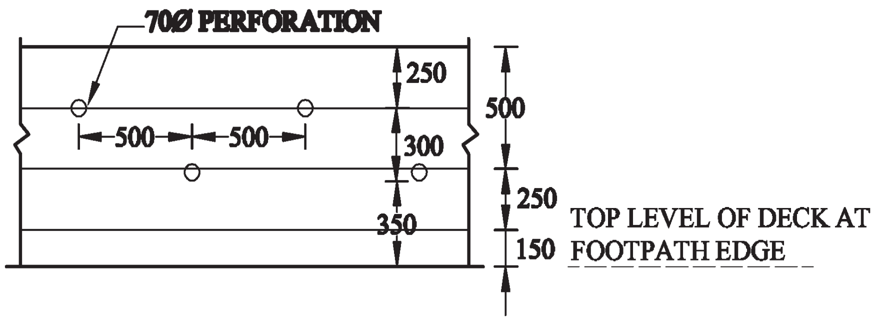
1. ABUTMENT AND WINGS IN VIBRATED CC **M15** (NOMINAL MIX) USING 40*mm* ISS SIZE HBG METAL.
2. BEDBLOCK CUM DIRT WALL IN VIBRATED RCC **M25** (DESIGN MIX) USING 20*mm* ISS SIZE HBG GRADED METAL.
3. PIER IN VIBRATED CC **M15** (NOMINAL MIX) USING 40*mm* ISS SIZE HBG METAL.
4. BEDBLOCK OVER PIER IN VIBRATED RCC **M25** (DESIGN MIX) USING 20*mm* ISS SIZE HBG GRADED METAL, 250 *mm* THICK.
5. DECK SLAB IN VIBRATED RCC **M25** (DESIGN MIX) USING 20*mm* ISS SIZE HBG GRADED METAL, ... *mm* THICK AT CENTRE AND .....*mm* THICK AT EDGES.
6. BASE COURSE IN VIBRATED CC **M15** (NOMINAL MIX), 150*mm* THICK.
7. APPROACH SLAB IN VIBRATED RCC **M30** (DESIGN MIX) USING 20*mm* ISS SIZE HBG GRADED METAL, *mm* THICK AT CENTRE AND 300 *mm* THICK AT ENDS.
8. HAND RAILS & POSTS IN VIBRATED RCC **M25** (DESIGN MIX) USING 20*mm* ISS SIZE HBG GRADED METAL AS PER GOI DRG. No. **SD/202**.
9. PARAPET WALL IN VIBRATED CC **M15** (NOMINAL MIX) USING 40*mm* ISS SIZE HBG METAL.
10. CC WEARING COAT IN VIBRATED CC **M30** (DESIGN MIX), 75*mm* UNIFORM THICK USING **IRC** GRADED METAL.
11. PVC EXPANSION JOINT 20 *mm* THICK.
12. GI DRAINAGE SPOUT 100 *mm* DIA, AS PER GOI DRG. No. **SD/205**.
13. FILTER MEDIA 600 *mm* THICK BEHIND ABUTMENT & WINGS AS PER **IRC:78-2000** (Appendix 6).
14. PVC SEEPAGE PIPES, 100 *mm* DIA. PLACED STAGGERED AT 1.0*m* SPACINGS BOTH HORIZONTALLY AND VERTICALLY IN ABUTMENT & WINGS.



DETAILS OF HAND RAILS, FOOTPATH & CRASH BARRIER

(SCALE - 1:40)

ALL DIMENSIONS ARE IN *mm.*

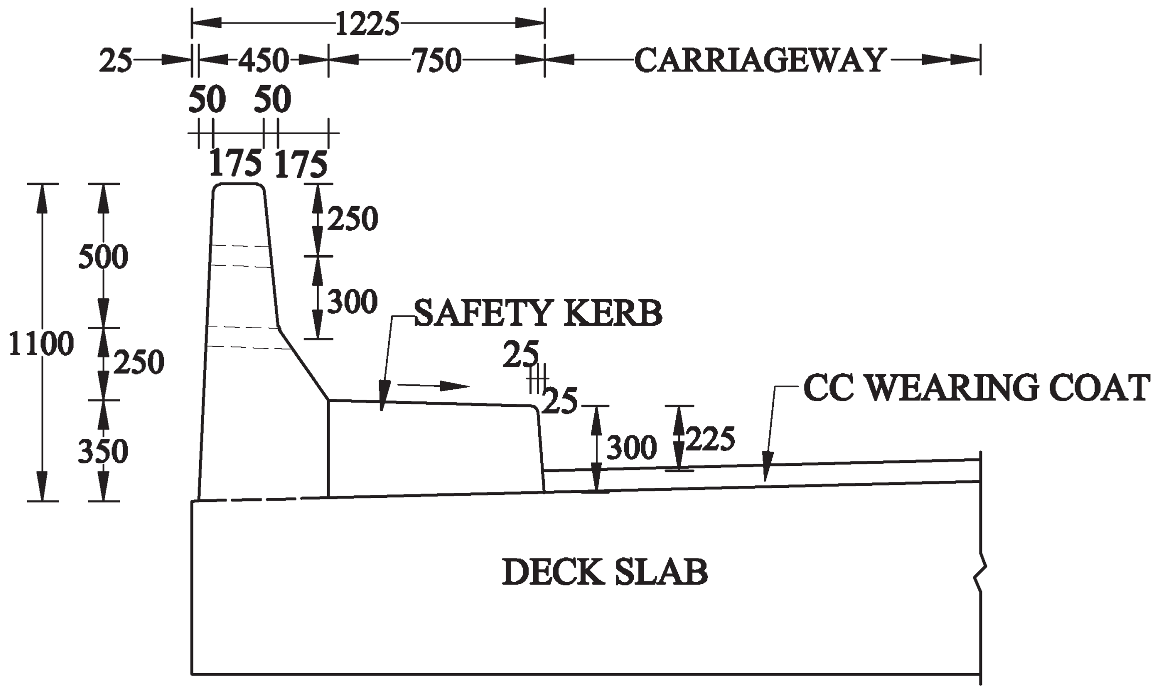


ELEVATION OF CRASH BARRIER SHOWING PERFORATIONS

(SCALE - 1:40)

ALL DIMENSIONS ARE IN *mm.*

Fig: 8.18

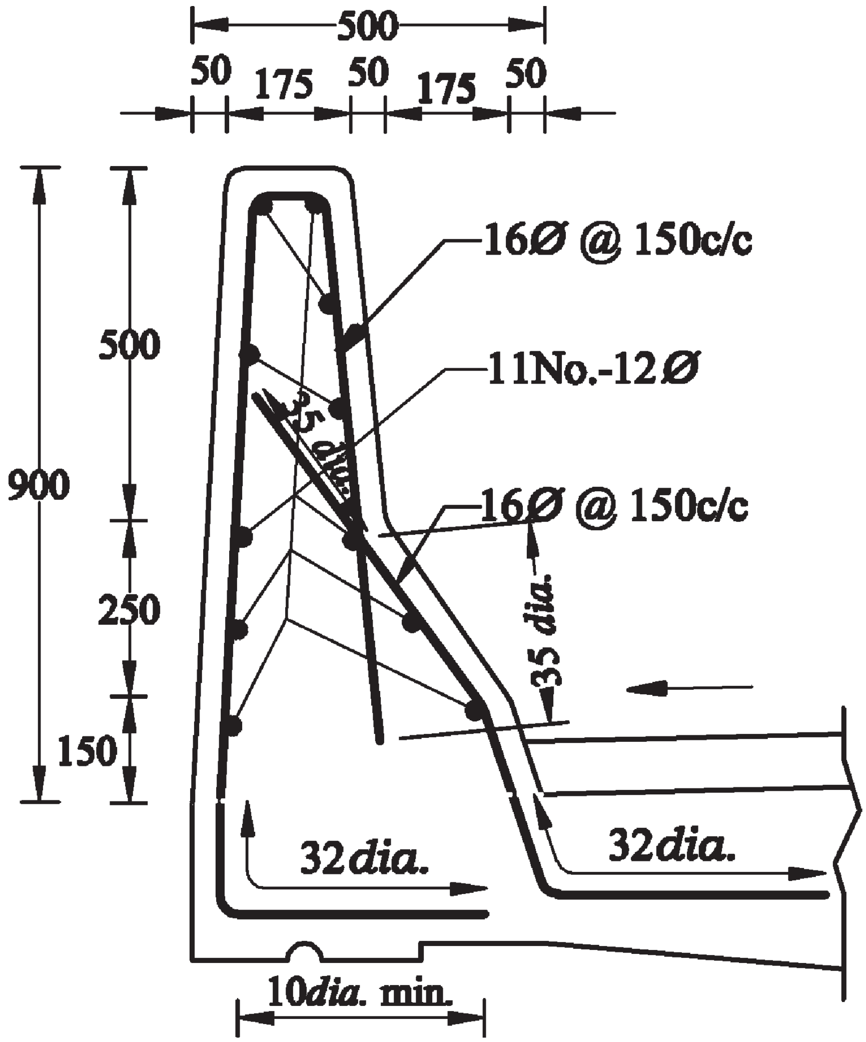


DETAILS OF SAFETY KERB FOR SUPERSTRUCTURE WITHOUT FOOTPATH

(SCALE - 1:40)

ALL DIMENSIONS ARE IN *mm.*

Fig: 8.19

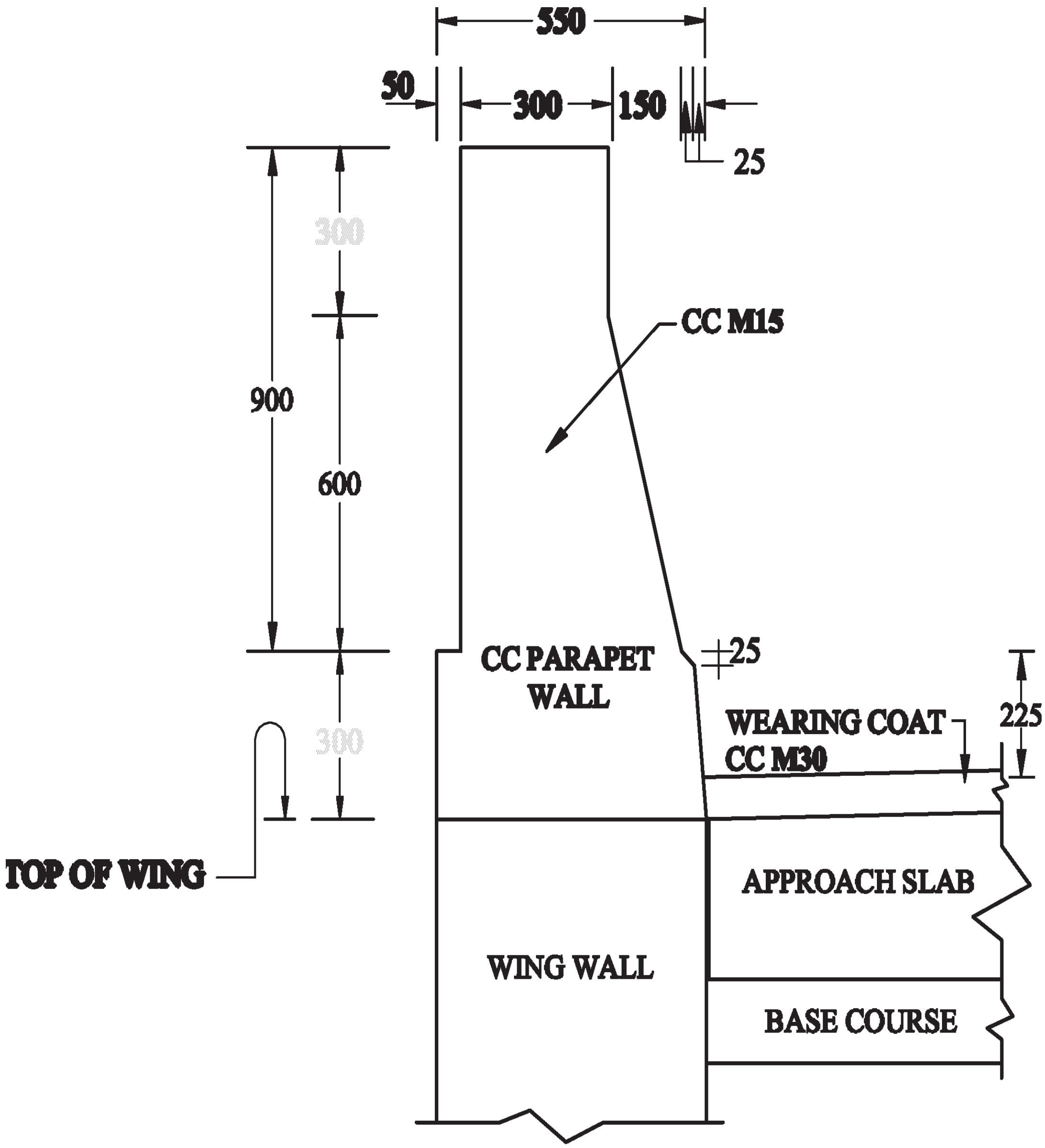


DETAILS OF RCC (M40) CRASH BARRIER WITHOUT SAFETY KERB

(SCALE - 1:20)

ALL DIMENSIONS ARE IN *mm.*

Fig: 8.20



DETAILS OF CC PARAPET WALL OVER WINGS

for

BRIDGE WITHOUT FOOTPATH

(SCALE - 1:20)

Fig: 8.21

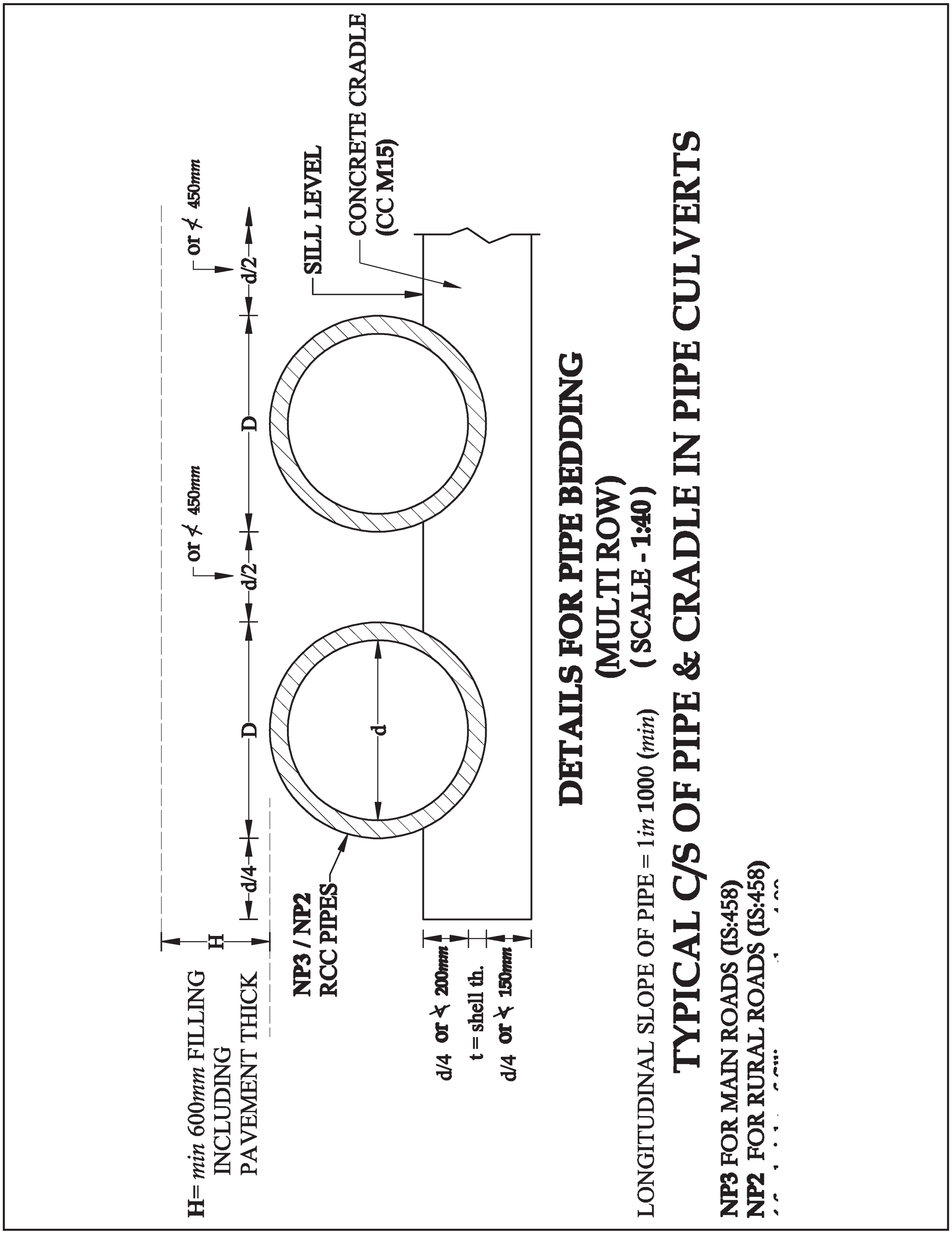

H= min 600mm FILLING
INCLUDING
PAVEMENT THICK
H
d/4
D
d
d/2
or ≮ 450mm
D
d/2
or ≮ 450mm
SILL LEVEL
CONCRETE CRADLE
(CC M15)
NP3 / NP2
RCC PIPES
d/4 or ≮ 200mm
t = shell th.
d/4 or ≮ 150mm
DETAILS FOR PIPE BEDDING
(MULTI ROW)
(SCALE - 1:40)
LONGITUDINAL SLOPE OF PIPE = 1 in 1000 (min)
TYPICAL C/S OF PIPE & CRADLE IN PIPE CULVERTS
NP3 FOR MAIN ROADS (IS:458)
NP2 FOR RURAL ROADS (IS:458)

Fig: 8.22

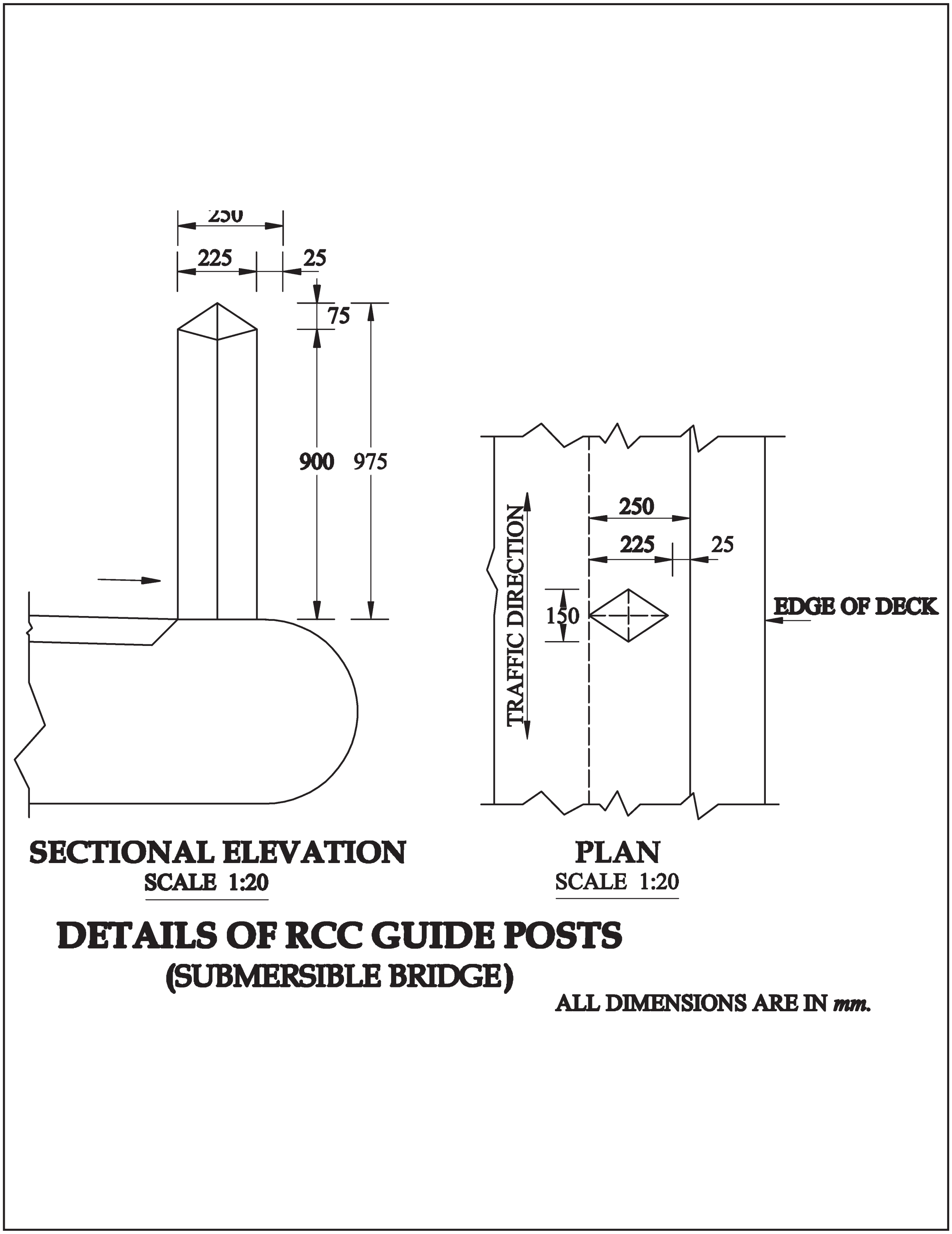

250
225
25
75
900
975
TRAFFIC DIRECTION
250
225
25
150
EDGE OF DECK
SECTIONAL ELEVATION
SCALE 1:20
PLAN
SCALE 1:20
DETAILS OF RCC GUIDE POSTS
(SUBMERSIBLE BRIDGE)
ALL DIMENSIONS ARE IN mm.

Fig: 8.23

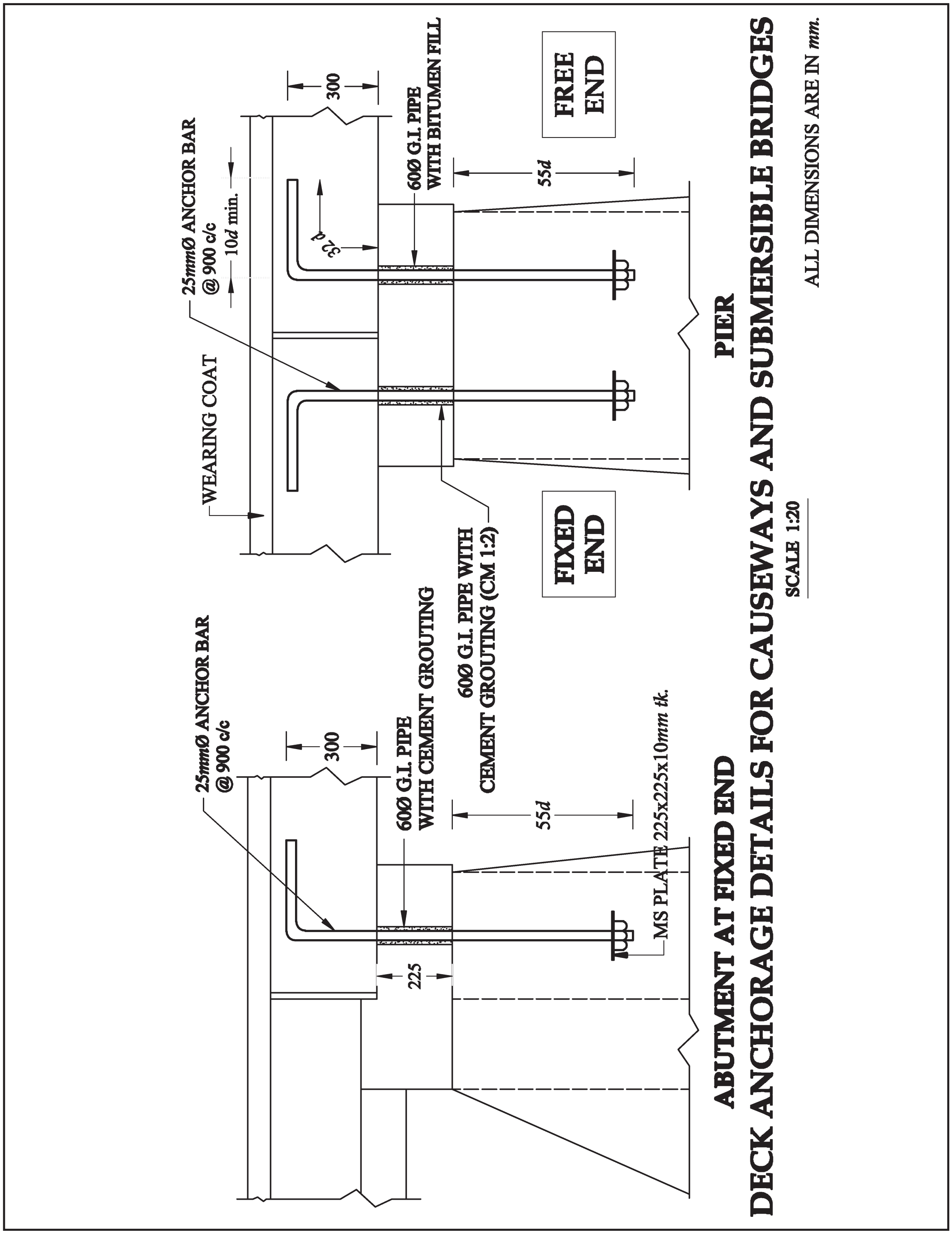

DECK ANCHORAGE DETAILS FOR CAUSEWAYS AND SUBMERSIBLE BRIDGES
SCALE 1:20
ALL DIMENSIONS ARE IN mm.
ABUTMENT AT FIXED END
PIER
FREE END
FIXED END
WEARING COAT
25mmØ ANCHOR BAR @ 900 c/c
25mmØ ANCHOR BAR @ 900 c/c
10d min.
60Ø G.I. PIPE WITH BITUMEN FILL
60Ø G.I. PIPE WITH CEMENT GROUTING (CM 1:2)
60Ø G.I. PIPE WITH CEMENT GROUTING
MS PLATE 225x225x10mm tk.
300
300
55d
55d
225

Fig: 8.24

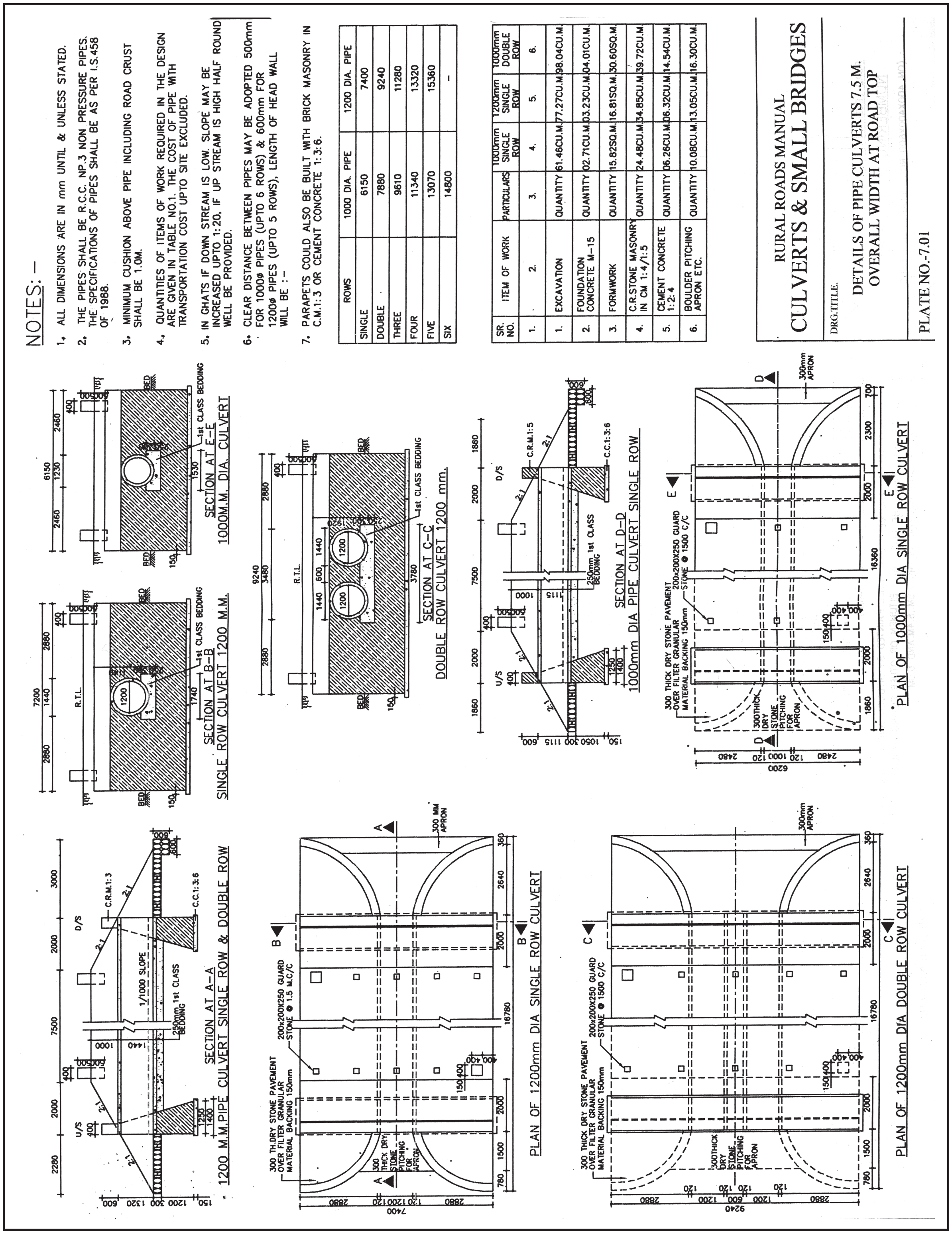

NOTES: –
1. ALL DIMENSIONS ARE IN mm UNTIL & UNLESS STATED.
2. THE PIPES SHALL BE R.C.C. NP.3 NON PRESSURE PIPES. THE SPECIFICATIONS OF PIPES SHALL BE AS PER I.S.458 OF 1988.
3. MINIMUM CUSHION ABOVE PIPE INCLUDING ROAD CRUST SHALL BE 1.0M.
4. QUANTITIES OF ITEMS OF WORK REQUIRED IN THE DESIGN ARE GIVEN IN TABLE NO.1. THE COST OF PIPE WITH TRANSPORTATION COST UPTO SITE EXCLUDED.
5. IN GHATS IF DOWN STREAM IS LOW. SLOPE MAY BE INCREASED UPTO 1:20, IF UP STREAM IS HIGH HALF ROUND WELL BE PROVIDED.
6. CLEAR DISTANCE BETWEEN PIPES MAY BE ADOPTED 500mm FOR 1000ø PIPES (UPTO 6 ROWS) & 600mm FOR 1200ø PIPES (UPTO 5 ROWS), LENGTH OF HEAD WALL WILL BE :–
7. PARAPETS COULD ALSO BE BUILT WITH BRICK MASONRY IN C.M.1:3 OR CEMENT CONCRETE 1:3:6.
ROWS | 1000 DIA. PIPE | 1200 DIA. PIPE
SINGLE | 6150 | 7400
DOUBLE | 7880 | 9240
THREE | 9610 | 11280
FOUR | 11340 | 13320
FIVE | 13070 | 15360
SIX | 14800 | –
SR. NO. | ITEM OF WORK | PARTICULARS | 1000mm SINGLE ROW | 1200mm SINGLE ROW | 1000mm DOUBLE ROW
1. | 2. | 3. | 4. | 5. | 6.
1. | EXCAVATION | QUANTITY | 61.46CU.M. | 77.27CU.M. | 98.04CU.M.
2. | FOUNDATION CONCRETE M–15 | QUANTITY | 02.71CU.M. | 03.23CU.M. | 04.01CU.M.
3. | FORMWORK | QUANTITY | 15.82SQ.M. | 16.81SQ.M. | 30.60SQ.M.
4. | C.R.STONE MASONRY IN CM 1:4/1:5 | QUANTITY | 24.48CU.M. | 34.85CU.M. | 39.72CU.M.
5. | CEMENT CONCRETE 1:2:4 | QUANTITY | 06.26CU.M. | 06.32CU.M. | 14.54CU.M.
6. | BOULDER PITCHING APRON ETC. | QUANTITY | 10.08CU.M. | 13.05CU.M. | 16.30CU.M.
SECTION AT A–A
1200 M.M.PIPE CULVERT SINGLE ROW & DOUBLE ROW
SECTION AT B–B
SINGLE ROW CULVERT 1200 M.M.
SECTION AT E–E
1000M.M. DIA. CULVERT
SECTION AT C–C
DOUBLE ROW CULVERT 1200 mm.
SECTION AT D–D
1000mm DIA PIPE CULVERT SINGLE ROW
PLAN OF 1200mm DIA SINGLE ROW CULVERT
PLAN OF 1200mm DIA DOUBLE ROW CULVERT
PLAN OF 1000mm DIA SINGLE ROW CULVERT
300 THICK DRY STONE PAVEMENT OVER FILTER GRANULAR MATERIAL BACKING 150mm
200x200X250 GUARD STONE @ 1500 C/C
300 THICK DRY STONE PITCHING FOR APRON
300mm APRON
1st CLASS BEDDING
C.R.M.1:3
C.C.1:3:6
1/1000 SLOPE
R.T.L.
RURAL ROADS MANUAL
CULVERTS & SMALL BRIDGES
DRG.TITLE.
DETAILS OF PIPE CULVERTS 7.5 M. OVERALL WIDTH AT ROAD TOP
PLATE NO.-7.01

Fig: 8.25

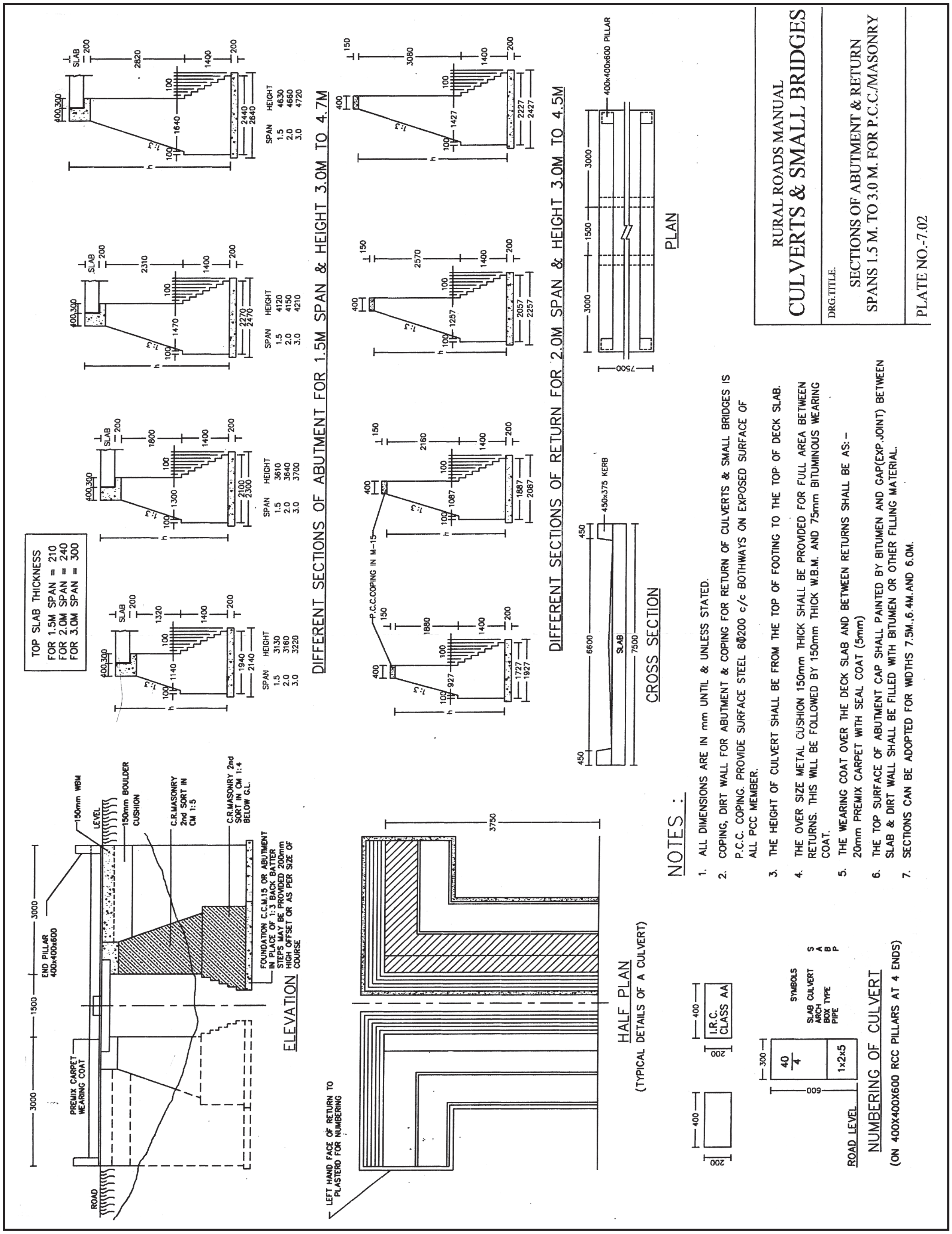

RURAL ROADS MANUAL
CULVERTS & SMALL BRIDGES
DRG.TITLE.
SECTIONS OF ABUTMENT & RETURN
SPANS 1.5 M. TO 3.0 M. FOR P.C.C./MASONRY
PLATE NO.-7.02
ELEVATION
HALF PLAN
(TYPICAL DETAILS OF A CULVERT)
NUMBERING OF CULVERT
(ON 400X400X600 RCC PILLARS AT 4 ENDS)
ROAD LEVEL
SYMBOLS
SLAB CULVERT S
ARCH A
BOX TYPE B
PIPE P
I.R.C. CLASS AA
LEFT HAND FACE OF RETURN TO PLASTERED FOR NUMBERING
TOP SLAB THICKNESS
FOR 1.5M SPAN = 210
FOR 2.0M SPAN = 240
FOR 3.0M SPAN = 300
DIFFERENT SECTIONS OF ABUTMENT FOR 1.5M SPAN & HEIGHT 3.0M TO 4.7M
DIFFERENT SECTIONS OF RETURN FOR 2.0M SPAN & HEIGHT 3.0M TO 4.5M
CROSS SECTION
PLAN
P.C.C.COPING IN M-15
450x375 KERB
400x400x600 PILLAR
END PILLAR 400x400x600
PREMIX CARPET WEARING COAT
150mm WBM
150mm BOULDER CUSHION
C.R.MASONRY 2nd SORT IN CM 1:5
C.R.MASONRY 2nd SORT IN CM 1:4 BELOW G.L.
FOUNDATION C.C.M.15 OR ABUTMENT IN PLACE OF 1:3 BACK BATTER STEPS MAY BE PROVIDED 200mm HIGH OFFSET OR AS PER SIZE OF COURSE
NOTES :
1. ALL DIMENSIONS ARE IN mm UNTIL & UNLESS STATED.
2. COPING, DIRT WALL FOR ABUTMENT & COPING FOR RETURN OF CULVERTS & SMALL BRIDGES IS P.C.C. COPING. PROVIDE SURFACE STEEL 8Ø200 c/c BOTHWAYS ON EXPOSED SURFACE OF ALL PCC MEMBER.
3. THE HEIGHT OF CULVERT SHALL BE FROM THE TOP OF FOOTING TO THE TOP OF DECK SLAB.
4. THE OVER SIZE METAL CUSHION 150mm THICK SHALL BE PROVIDED FOR FULL AREA BETWEEN RETURNS. THIS WILL BE FOLLOWED BY 150mm THICK W.B.M. AND 75mm BITUMINOUS WEARING COAT.
5. THE WEARING COAT OVER THE DECK SLAB AND BETWEEN RETURNS SHALL BE AS:– 20mm PREMIX CARPET WITH SEAL COAT (5mm)
6. THE TOP SURFACE OF ABUTMENT CAP SHALL PAINTED BY BITUMEN AND GAP(EXP.JOINT) BETWEEN SLAB & DIRT WALL SHALL BE FILLED WITH BITUMEN OR OTHER FILLING MATERIAL.
7. SECTIONS CAN BE ADOPTED FOR WIDTHS 7.5M.,6.4M.AND 6.0M.

Fig: 8.26

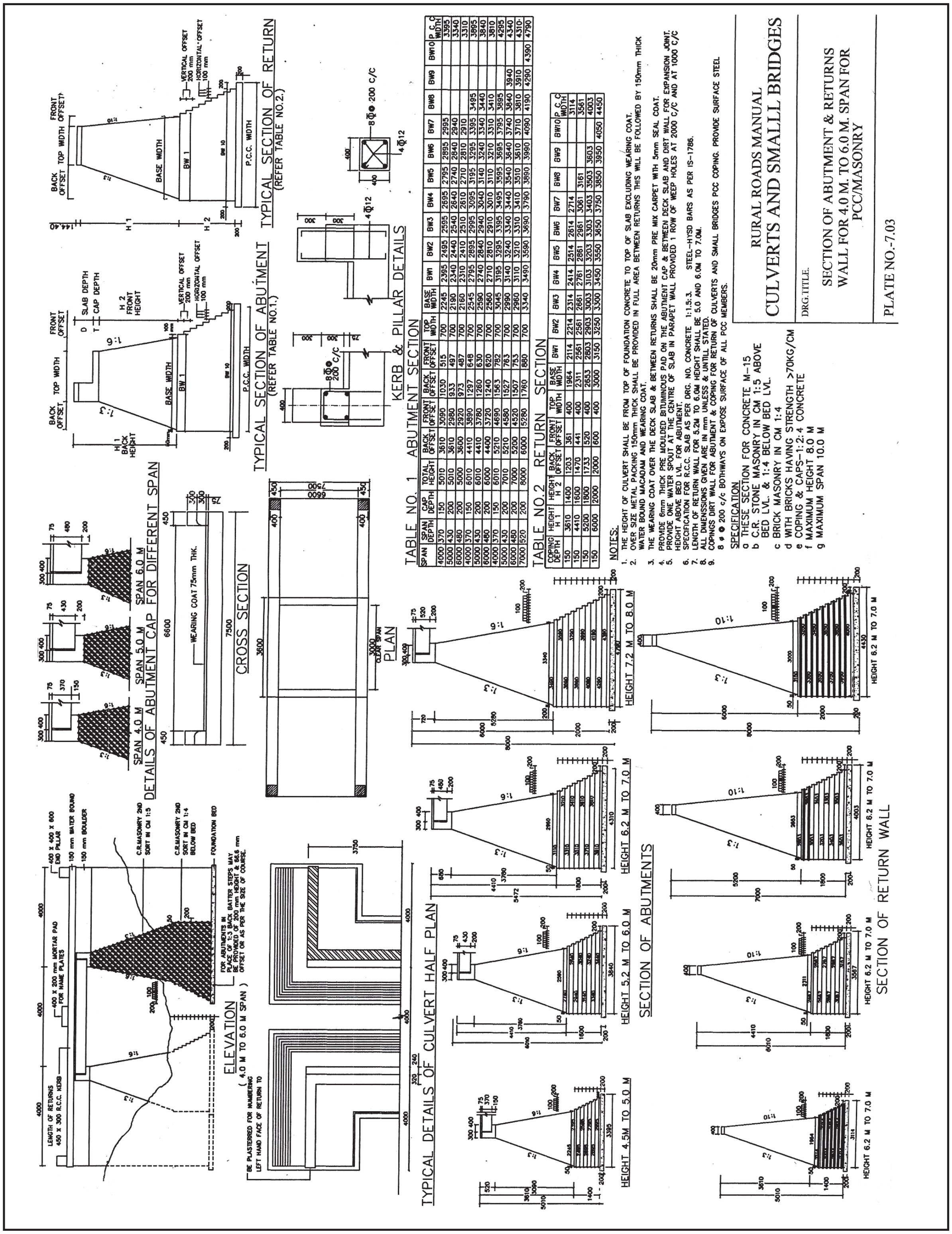

RURAL ROADS MANUAL
CULVERTS AND SMALL BRIDGES
SECTION OF ABUTMENT & RETURNS WALL FOR 4.0 M. TO 6.0 M. SPAN FOR PCC/MASONRY
PLATE NO.-7.03
TYPICAL SECTION OF RETURN
TYPICAL SECTION OF ABUTMENT
KERB & PILLAR DETAILS
TABLE NO. 1 ABUTMENT SECTION
TABLE NO. 2 RETURN SECTION
NOTES:
SPECIFICATION
ELEVATION
DETAILS OF ABUTMENT CAP FOR DIFFERENT SPAN
CROSS SECTION
PLAN
TYPICAL DETAILS OF CULVERT HALF PLAN
SECTION OF ABUTMENTS
SECTION OF RETURN WALL

Fig: 8.27

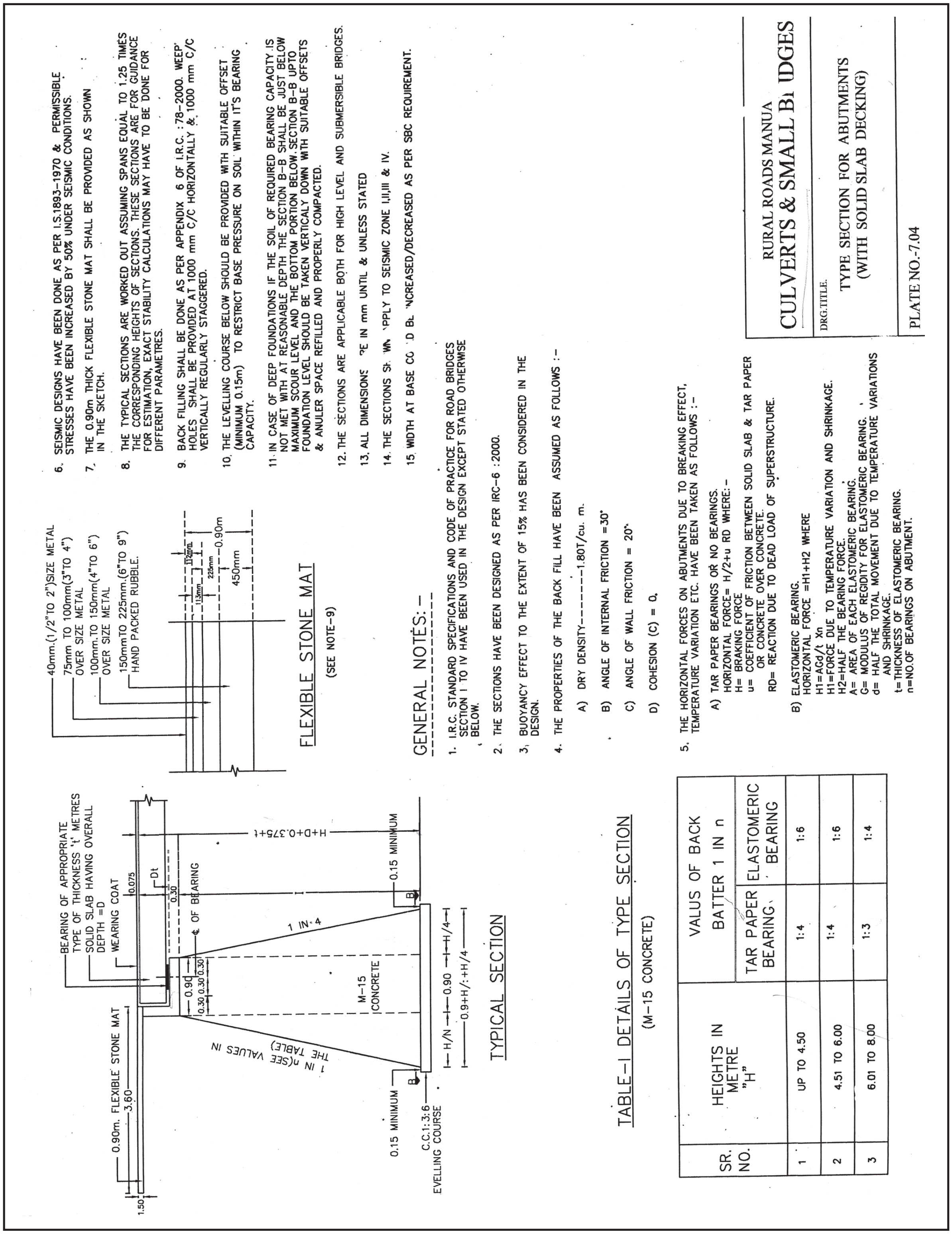

BEARING OF APPROPRIATE TYPE OF THICKNESS 't' METRES
SOLID SLAB HAVING OVERALL DEPTH =D
WEARING COAT
0.90m. FLEXIBLE STONE MAT
3.60
1.50
0.075
Dt
0.30
0.90
0.30 0.30 0.30
℄ OF BEARING
1 IN n(SEE VALUES IN THE TABLE)
1 IN 4
H+D+0.375+t
M-15 CONCRETE
0.15 MINIMUM
0.15 MINIMUM
B
B
C.C.1:3:6 EVELLING COURSE
H/N 0.90 H/4
0.9+H/:+H/4
TYPICAL SECTION
40mm.(1/2"TO 2")SIZE METAL
75mm TO 100mm(3"TO 4") OVER SIZE METAL
100mm.TO 150mm(4"TO 6") OVER SIZE METAL
150mmTO 225mm.(6"TO 9") HAND PACKED RUBBLE.
112mm
113mm
225mm
0.90m
450mm
FLEXIBLE STONE MAT
(SEE NOTE-9)
GENERAL NOTES:-
1. I.R.C. STANDARD SPECIFICATIONS AND CODE OF PRACTICE FOR ROAD BRIDGES SECTION I TO IV HAVE BEEN USED IN THE DESIGN EXCEPT STATED OTHERWISE BELOW.
2. THE SECTIONS HAVE BEEN DESIGNED AS PER IRC-6 :2000.
3. BUOYANCY EFFECT TO THE EXTENT OF 15% HAS BEEN CONSIDERED IN THE DESIGN.
4. THE PROPERTIES OF THE BACK FILL HAVE BEEN ASSUMED AS FOLLOWS :-
A) DRY DENSITY-------1.80T/cu. m.
B) ANGLE OF INTERNAL FRICTION =30°
C) ANGLE OF WALL FRICTION = 20°
D) COHESION (C) = 0.
5. THE HORIZONTAL FORCES ON ABUTMENTS DUE TO BREAKING EFFECT, TEMPERATURE VARIATION ETC. HAVE BEEN TAKEN AS FOLLOWS :-
A) TAR PAPER BEARINGS OR NO BEARINGS.
HORIZONTAL FORCE= H/2+u RD WHERE:-
H= BRAKING FORCE
u= COEFFICIENT OF FRICTION BETWEEN SOLID SLAB & TAR PAPER OR CONCRETE OVER CONCRETE.
RD= REACTION DUE TO DEAD LOAD OF SUPERSTRUCTURE.
B) ELASTOMERIC BEARING.
HORIZONTAL FORCE =H1+H2 WHERE
H1=AGd/t Xn
H1=FORCE DUE TO TEMPERATURE VARIATION AND SHRINKAGE.
H2=HALF THE BEARING FORCE.
A= AREA OF EACH ELASTOMERIC BEARING.
G= MODULUS OF REGIDITY FOR ELASTOMERIC BEARING.
d= HALF THE TOTAL MOVEMENT DUE TO TEMPERATURE VARIATIONS AND SHRINKAGE.
t=THICKNESS OF ELASTOMERIC BEARING.
n=NO.OF BEARINGS ON ABUTMENT.
6. SEISMIC DESIGNS HAVE BEEN DONE AS PER I.S.1893-1970 & PERMISSIBLE STRESSES HAVE BEEN INCREASED BY 50% UNDER SEISMIC CONDITIONS.
7. THE 0.90m THICK FLEXIBLE STONE MAT SHALL BE PROVIDED AS SHOWN IN THE SKETCH.
8. THE TYPICAL SECTIONS ARE WORKED OUT ASSUMING SPANS EQUAL TO 1.25 TIMES THE CORRESPONDING HEIGHTS OF SECTIONS. THESE SECTIONS ARE FOR GUIDANCE FOR ESTIMATION, EXACT STABILITY CALCULATIONS MAY HAVE TO BE DONE FOR DIFFERENT PARAMETRES.
9. BACK FILLING SHALL BE DONE AS PER APPENDIX 6 OF I.R.C. :78-2000. WEEP HOLES SHALL BE PROVIDED AT 1000 mm C/C HORIZONTALLY & 1000 mm C/C VERTICALLY REGULARLY STAGGERED.
10. THE LEVELLING COURSE BELOW SHOULD BE PROVIDED WITH SUITABLE OFFSET (MINIMUM 0.15m) TO RESTRICT BASE PRESSURE ON SOIL WITHIN IT'S BEARING CAPACITY.
11. IN CASE OF DEEP FOUNDATIONS IF THE SOIL OF REQUIRED BEARING CAPACITY IS NOT MET WITH AT REASONABLE DEPTH THE SECTION B-B SHALL BE JUST BELOW MAXIMUM SCOUR LEVEL AND THE BOTTOM PORTION BELOW SECTION B-B UPTO FOUNDATION LEVEL SHOULD BE TAKEN VERTICALY DOWN WITH SUITABLE OFFSETS & ANULER SPACE REFILLED AND PROPERLY COMPACTED.
12. THE SECTIONS ARE APPLICABLE BOTH FOR HIGH LEVEL AND SUBMERSIBLE BRIDGES.
13. ALL DIMENSIONS ARE IN mm UNTIL & UNLESS STATED
14. THE SECTIONS SHALL APPLY TO SEISMIC ZONE I,II,III & IV.
15. WIDTH AT BASE CO D BE INCREASED/DECREASED AS PER SBC REQUIREMENT.
TABLE-I DETAILS OF TYPE SECTION
(M-15 CONCRETE)
SR. NO.
HEIGHTS IN METRE "H"
VALUS OF BACK BATTER 1 IN n
TAR PAPER BEARING
ELASTOMERIC BEARING
1
UP TO 4.50
1:4
1:6
2
4.51 TO 6.00
1:4
1:6
3
6.01 TO 8.00
1:3
1:4
RURAL ROADS MANUA
CULVERTS & SMALL B IDGES
DRG.TITLE.
TYPE SECTION FOR ABUTMENTS
(WITH SOLID SLAB DECKING)
PLATE NO.-7.04

Fig: 8.28

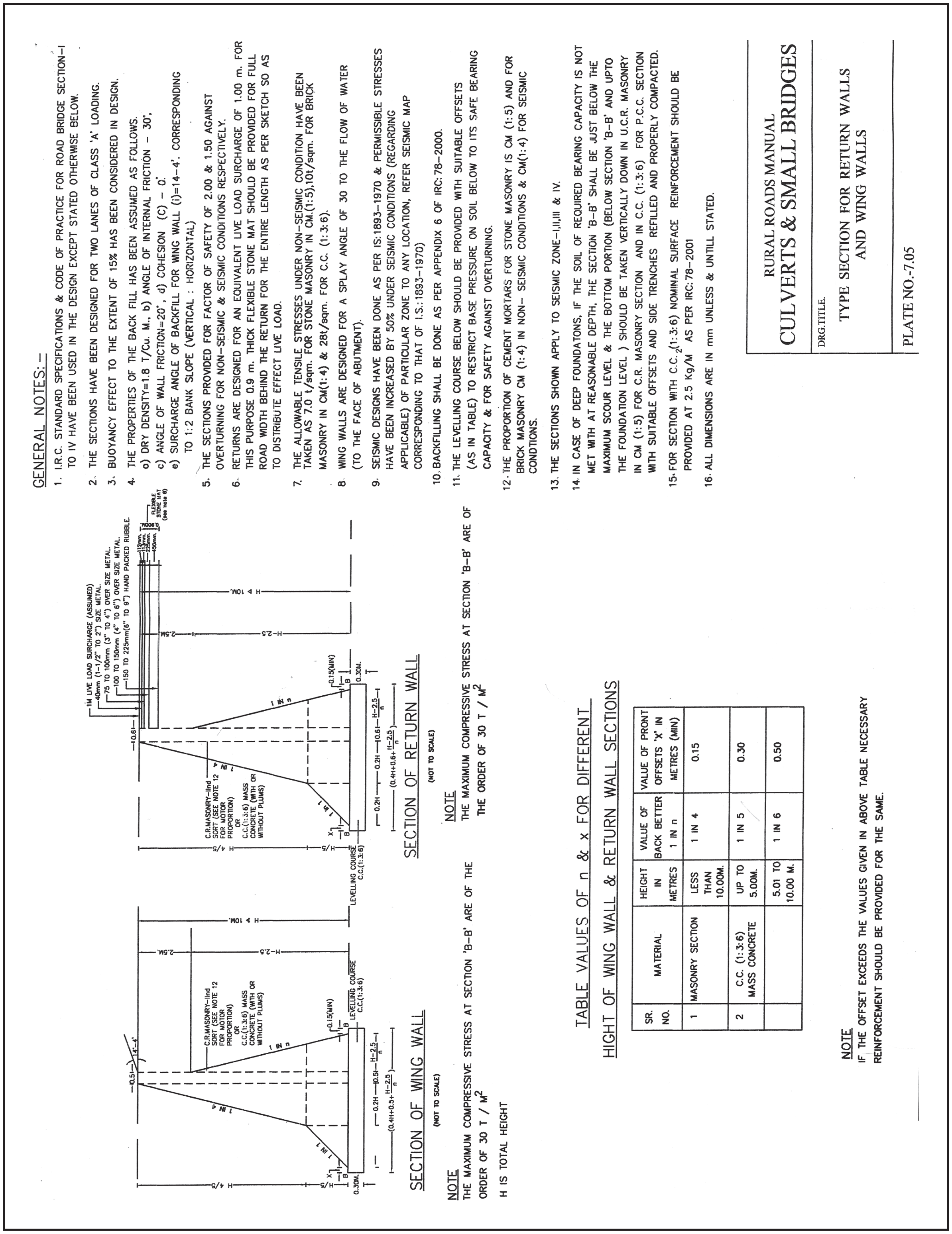

SECTION OF WING WALL
(NOT TO SCALE)
NOTE
THE MAXIMUM COMPRESSIVE STRESS AT SECTION 'B-B' ARE OF THE ORDER OF 30 T / M2
H IS TOTAL HEIGHT
SECTION OF RETURN WALL
(NOT TO SCALE)
NOTE
THE MAXIMUM COMPRESSIVE STRESS AT SECTION 'B-B' ARE OF THE ORDER OF 30 T / M2
C.R.MASONRY-IInd SORT (SEE NOTE 12 FOR MOTOR PROPORTION) OR C.C.(1:3:6) MASS CONCRETE (WITH OR WITHOUT PLUMS)
LEVELLING COURSE C.C.(1:3:6)
1M LIVE LOAD SURCHARGE (ASSUMED)
40mm (1-1/2" TO 2") SIZE METAL.
75 TO 100mm (3" TO 4") OVER SIZE METAL.
100 TO 150mm (4" TO 6") OVER SIZE METAL.
150 TO 225mm(6" TO 9") HAND PACKED RUBBLE.
FLEXIBLE STONE MAT (see note 6)
TABLE VALUES OF n & x FOR DIFFERENT HIGHT OF WING WALL & RETURN WALL SECTIONS
SR. NO. | MATERIAL | HEIGHT IN METRES | VALUE OF BACK BETTER 1 IN n | VALUE OF PRONT OFFSETS 'X' IN METRES (MIN)
1 | MASONRY SECTION | LESS THAN 10.00M. | 1 IN 4 | 0.15
2 | C.C. (1:3:6) MASS CONCRETE | UP TO 5.00M. | 1 IN 5 | 0.30
 | | 5.01 TO 10.00 M. | 1 IN 6 | 0.50
NOTE
IF THE OFFSET EXCEEDS THE VALUES GIVEN IN ABOVE TABLE NECESSARY REINFORCEMENT SHOULD BE PROVIDED FOR THE SAME.
GENERAL NOTES:-
1. I.R.C. STANDARD SPECIFICATIONS & CODE OF PRACTICE FOR ROAD BRIDGE SECTION-I TO IV HAVE BEEN USED IN THE DESIGN EXCEPT STATED OTHERWISE BELOW.
2. THE SECTIONS HAVE BEEN DESIGNED FOR TWO LANES OF CLASS 'A' LOADING.
3. BUOYANCY EFFECT TO THE EXTENT OF 15% HAS BEEN CONSIDERED IN DESIGN.
4. THE PROPERTIES OF THE BACK FILL HAS BEEN ASSUMED AS FOLLOWS.
a) DRY DENSITY=1.8 T/Cu. M., b) ANGLE OF INTERNAL FRICTION - 30°,
c) ANGLE OF WALL FRICTION=20°, d) COHESION (C) - 0.
e) SURCHARGE ANGLE OF BACKFILL FOR WING WALL (i)=14-4'. CORRESPONDING TO 1:2 BANK SLOPE (VERTICAL : HORIZONTAL)
5. THE SECTIONS PROVIDED FOR FACTOR OF SAFETY OF 2.00 & 1.50 AGAINST OVERTURNING FOR NON-SEISMIC & SEISMIC CONDITIONS RESPECTIVELY.
6. RETURNS ARE DESIGNED FOR AN EQUIVALENT LIVE LOAD SURCHARGE OF 1.00 m. FOR THIS PURPOSE 0.9 m. THICK FLEXIBLE STONE MAT SHOULD BE PROVIDED FOR FULL ROAD WIDTH BEHIND THE RETURN FOR THE ENTIRE LENGTH AS PER SKETCH SO AS TO DISTRIBUTE EFFECT LIVE LOAD.
7. THE ALLOWABLE TENSILE STRESSES UNDER NON-SEISMIC CONDITION HAVE BEEN TAKEN AS 7.0 t/sqm. FOR STONE MASONRY IN CM.(1:5),10t/sqm. FOR BRICK MASONRY IN CM(1:4) & 28t/sqm. FOR C.C. (1:3:6).
8. WING WALLS ARE DESIGNED FOR A SPLAY ANGLE OF 30 TO THE FLOW OF WATER (TO THE FACE OF ABUTMENT).
9. SEISMIC DESIGNS HAVE BEEN DONE AS PER IS:1893-1970 & PERMISSIBLE STRESSES HAVE BEEN INCREASED BY 50% UNDER SEISMIC CONDITIONS (REGARDING APPLICABLE) OF PARTICULAR ZONE TO ANY LOCATION, REFER SEISMIC MAP CORRESPONDING TO THAT OF I.S.:1893-1970)
10. BACKFILLING SHALL BE DONE AS PER APPENDIX 6 OF IRC:78-2000.
11. THE LEVELLING COURSE BELOW SHOULD BE PROVIDED WITH SUITABLE OFFSETS (AS IN TABLE) TO RESTRICT BASE PRESSURE ON SOIL BELOW TO ITS SAFE BEARING CAPACITY & FOR SAFETY AGAINST OVERTURNING.
12. THE PROPORTION OF CEMENT MORTARS FOR STONE MASONRY IS CM (1:5) AND FOR BRICK MASONRY CM (1:4) IN NON- SEISMIC CONDITIONS & CM(1:4) FOR SEISMIC CONDTIONS.
13. THE SECTIONS SHOWN APPLY TO SEISMIC ZONE-I,II,III & IV.
14. IN CASE OF DEEP FOUNDATONS, IF THE SOIL OF REQUIRED BEARING CAPACITY IS NOT MET WITH AT REASONABLE DEPTH, THE SECTION 'B-B' SHALL BE JUST BELOW THE MAXIMUM SCOUR LEVEL & THE BOTTOM PORTION (BELOW SECTION 'B-B' AND UPTO THE FOUNDATION LEVEL) SHOULD BE TAKEN VERTICALLY DOWN IN U.C.R. MASONRY IN CM (1:5) FOR C.R. MASONRY SECTION AND IN C.C. (1:3:6) FOR P.C.C. SECTION WITH SUITABLE OFFSETS AND SIDE TRENCHES REFILLED AND PROPERLY COMPACTED.
15. FOR SECTION WITH C.C. (1:3:6) NOMINAL SURFACE REINFORCEMENT SHOULD BE PROVIDED AT 2.5 Kg/M2 AS PER IRC:78-2001
16. ALL DIMENSIONS ARE IN mm UNLESS & UNTILL STATED.
RURAL ROADS MANUAL
CULVERTS & SMALL BRIDGES
DRG.TITLE.
TYPE SECTION FOR RETURN WALLS AND WING WALLS
PLATE NO.-7.05

Fig: 8.29

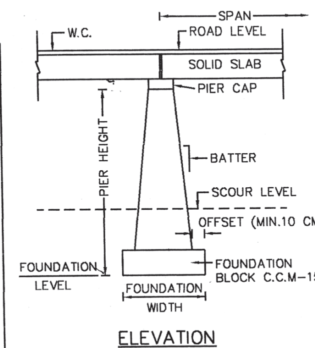
TABLE-I

SECTION DESIGNATION NO. FOR VARIOUS SPAN & HEIGHT.

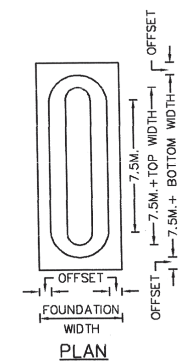
HEIGHT	CR STONE MASONRY IInd SORT IN			P.C.C. M-15	FOUNDATION WIDTH IN mm	
	CM.1:5	CM.1:4	CM.1:3		ON SOIL	ON ROCK
SPAN 5M.						
4.0	9	6	5	3	1850	2030
4.4	10	6	5	2	2000	2200
4.8	10	7	5	2	2100	2300
5.0	10	7	5	2	2200	2300
5.2	10	10	5	2	2200	2400
SPAN 6M.						
4.7	9	6	5	1	2000	2300
5.0	10	7	6	3	2300	2500
6.3	10	8	6	3	2400	2700
6.7	10	8	6	3	2600	2800
7.1	10	8	6	3	2600	2900
SPAN 7M.						
5.6	10	7	5	2	2300	2400
6.4	10	7	5	3	2400	2600
7.2	10	7	6	3	2600	2800
8.0	10	7	6	3	2800	3000
8.8	10	7	6	3	2800	3300
SPAN 8M.						
6.4	10	7	5	2	2300	2600
7.2	10	7	5	3	2400	2700
8.0	10	8	6	3	2400	2700
8.8	10	8	6	3	2700	3200
9.6	10	8	6	3	2800	3300
SPAN 9M.						
7.2	10	7	5	3	2600	2800
8.0	10	7	5	3	2700	3000
8.8	10	7	6	3	3000	3300
9.6	10	7	6	4	3000	3500
10.4	10	7	6	4	3000	3500
SPAN 10M.						
8.0	10	7	5	3	2700	3000
8.8	10	7	5	3	3000	3300
9.6	10	7	5	4	3300	3500
10.4	10	7	6	4	3300	3700
11.2	10	7	6	4	3400	3900

TABLE-II

SECTION DESIGNATION NO.	TOP WIDTH (mm)	BATTER
1	900	VERTICAL
2	1000	VERTICAL
3	1200	VERTICAL
4	750	1 IN 30
5	750	1 IN 25
6	900	1 IN 30
7	750	1 IN 20
8	900	1 IN 25
9	1000	1 IN 30
10	1000	1 IN 25



ELEVATION



PLAN

NOTES :-

1. DESIGN DATA ASSUMED FOR DESIGN.
   1.1 VELOCITY UPTO 4.5M./SEC.
   1.2 LIVE LOAD.
   I.R.C. CLASS A 2-LANES.
   1.3 SUPERSTRUCTURE R.C.C. SOLID SLAB.
   1.4 BUYANCY
   FOUNDATION RESTING ON SOIL 100%
   FOUNDATION RESTING ON ROCK 50%
2. TYPE PLAN IS ALSO APPLICABLE TO SUBMERSIBLE BRIDGE.
3. S.B.C. OF FOUNDING STRATA 30 TON/M^2
4. SEISMIC EFFECT IS NOT CONSIDERED.
5. FOUNDATION DEPTH
   5.1 FOR FOUNDATION ON SOIL THE MINIMUM DEPTH SHOULD BE 2M. BELOW SCOUR LEVEL.
   5.2 ANNULAR GAP SHOULD BE FULLY FILLED IN AND RAmmED.
   5.3 EMBEDMENT IN SOFT ROCK AND HARD ROCK SHOULD BE 1.5M. & 0.6M. RESPECTIVELY. FOR EXPOSED ROCK EMBEDMENT SHOULD BE 1.5M.
6. PROVIDE FOUNDATION BLOCK 0.2M. WITH MINIMUM OFFSET OF 0.1M. AS SHOWN IN FIGURE.
7. ANNULAR GAP AROUND PIER SHALL BE FILLED UPTO ROCK TOP LEVEL BY M-10 CONCRETE.

RURAL ROADS MANUAL

CULVERTS & SMALL BRIDGES

DRG.TITLE.

SECTION OF PIERS FOR HEIGHT UPTO 7.5 M. MASONRY/P.C.C.

PLATE NO.-7.06

Fig: 8.30

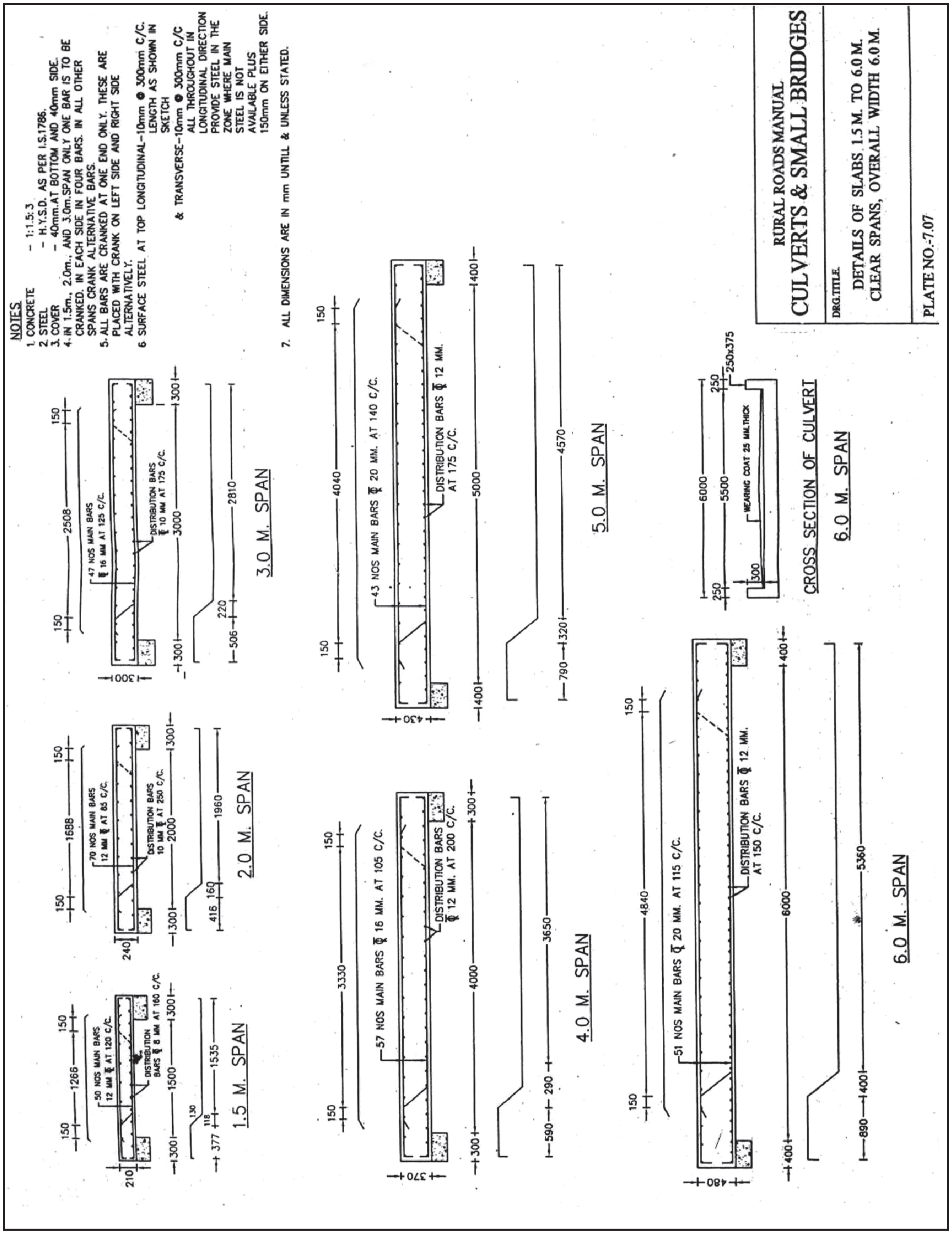

NOTES
1. CONCRETE - 1:1.5:3
2. STEEL - H.Y.S.D. AS PER I.S.1786.
3. COVER - 40mm.AT BOTTOM AND 40mm SIDE.
4. IN 1.5m., 2.0m., AND 3.0m.SPAN ONLY ONE BAR IS TO BE CRANKED. IN EACH SIDE IN FOUR BARS. IN ALL OTHER SPANS CRANK ALTERNATIVE BARS.
5. ALL BARS ARE CRANKED AT ONE END ONLY. THESE ARE PLACED WITH CRANK ON LEFT SIDE AND RIGHT SIDE ALTERNATIVELY.
6 SURFACE STEEL AT TOP LONGITUDINAL-10mm @ 300mm C/C. LENGTH AS SHOWN IN SKETCH
& TRANSVERSE-10mm @ 300mm C/C ALL THROUGHOUT IN LONGITUDINAL DIRECTION PROVIDE STEEL IN THE ZONE WHERE MAIN STEEL IS NOT AVAILABLE PLUS 150mm ON EITHER SIDE.
7. ALL DIMENSIONS ARE IN mm UNTILL & UNLESS STATED.
50 NOS MAIN BARS 12 MM Φ AT 120 C/C.
DISTRIBUTION BARS Φ 8 MM AT 160 C/C.
1.5 M. SPAN
70 NOS MAIN BARS 12 MM Φ AT 85 C/C.
DISTRIBUTION BARS 10 MM Φ AT 250 C/C.
2.0 M. SPAN
47 NOS MAIN BARS Φ 16 MM AT 125 C/C.
DISTRIBUTION BARS Φ 10 MM AT 175 C/C.
3.0 M. SPAN
57 NOS MAIN BARS Φ 16 MM. AT 105 C/C.
DISTRIBUTION BARS Φ 12 MM. AT 200 C/C.
4.0 M. SPAN
43 NOS MAIN BARS Φ 20 MM. AT 140 C/C.
DISTRIBUTION BARS Φ 12 MM. AT 175 C/C.
5.0 M. SPAN
51 NOS MAIN BARS Φ 20 MM. AT 115 C/C.
DISTRIBUTION BARS Φ 12 MM. AT 150 C/C.
6.0 M. SPAN
WEARING COAT 25 MM.THICK
CROSS SECTION OF CULVERT
6.0 M. SPAN
RURAL ROADS MANUAL
CULVERTS & SMALL BRIDGES
DRG.TITLE
DETAILS OF SLABS 1.5 M. TO 6.0 M.
CLEAR SPANS, OVERALL WIDTH 6.0 M.
PLATE NO.-7.07

Fig: 8.31

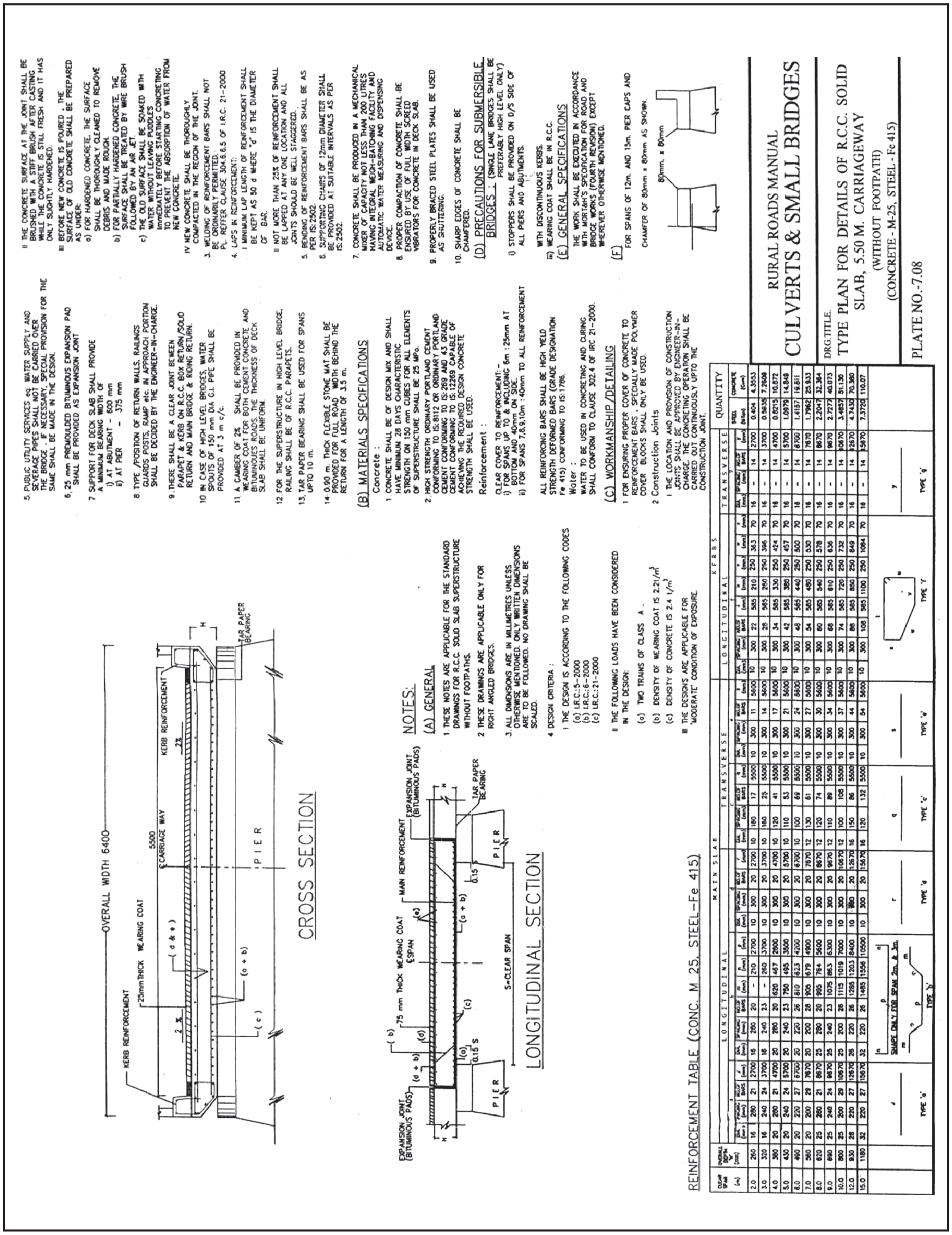

CROSS SECTION
LONGITUDINAL SECTION
NOTES:
RURAL ROADS MANUAL
CULVERTS & SMALL BRIDGES
DRG.TITLE.
TYPE PLAN FOR DETAILS OF R.C.C. SOLID SLAB, 5.50 M. CARRIAGEWAY
(WITHOUT FOOTPATH)
(CONCRETE - M-25, STEEL - Fe 415)
PLATE NO.-7.08

Fig: 8.32

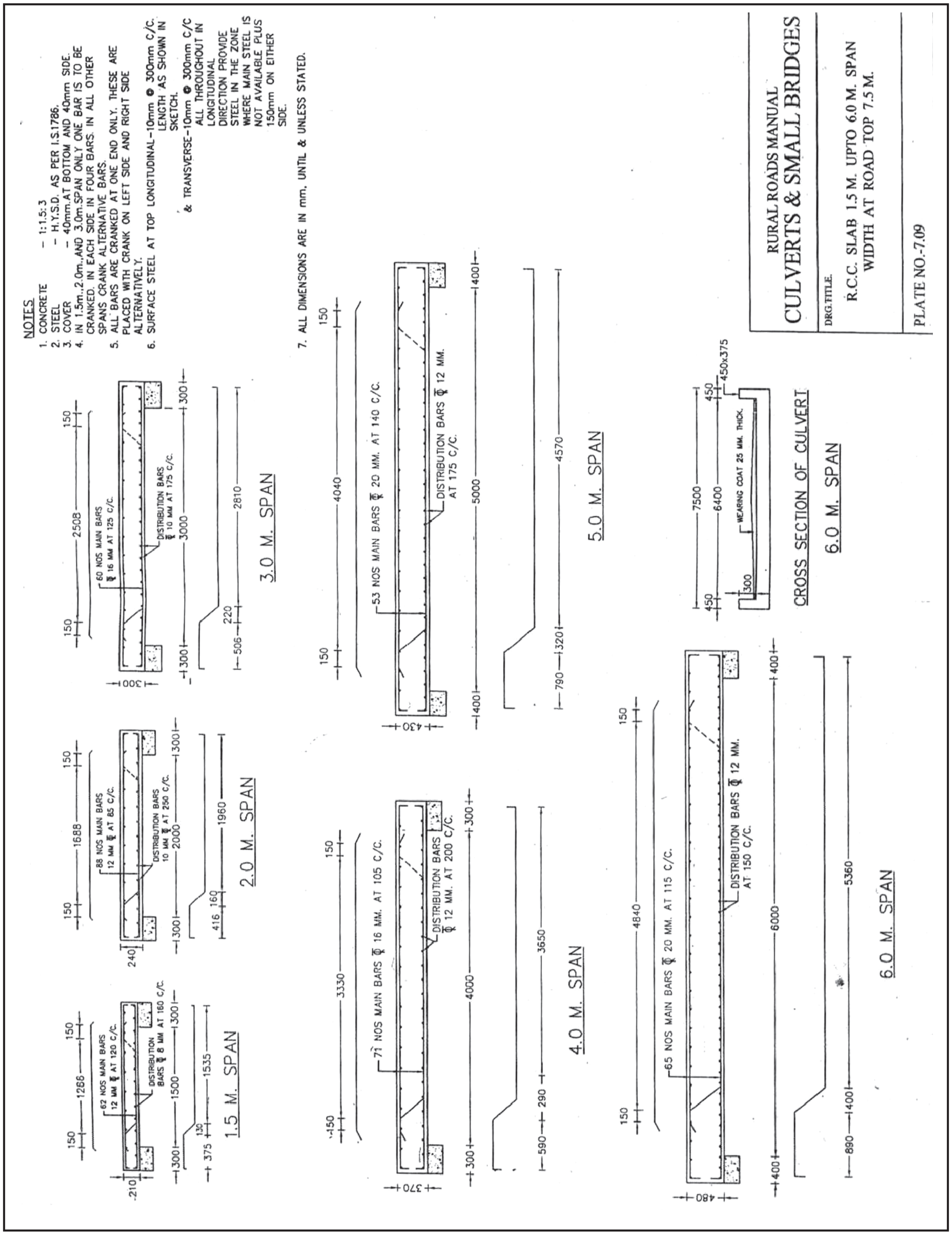

NOTES
1. CONCRETE - 1:1.5:3
2. STEEL - H.Y.S.D. AS PER I.S.1786.
3. COVER - 40mm.AT BOTTOM AND 40mm SIDE.
4. IN 1.5m.,2.0m.,AND 3.0m.SPAN ONLY ONE BAR IS TO BE CRANKED. IN EACH SIDE IN FOUR BARS. IN ALL OTHER SPANS CRANK ALTERNATIVE BARS.
5. ALL BARS ARE CRANKED AT ONE END ONLY. THESE ARE PLACED WITH CRANK ON LEFT SIDE AND RIGHT SIDE ALTERNATIVELY.
6. SURFACE STEEL AT TOP LONGITUDINAL-10mm @ 300mm C/C. LENGTH AS SHOWN IN SKETCH. & TRANSVERSE-10mm @ 300mm C/C ALL THROUGHOUT IN LONGITUDINAL DIRECTION PROVIDE STEEL IN THE ZONE WHERE MAIN STEEL IS NOT AVAILABLE PLUS 150mm ON EITHER SIDE.
7. ALL DIMENSIONS ARE IN mm. UNTIL & UNLESS STATED.
1.5 M. SPAN
2.0 M. SPAN
3.0 M. SPAN
4.0 M. SPAN
5.0 M. SPAN
6.0 M. SPAN
CROSS SECTION OF CULVERT
6.0 M. SPAN
RURAL ROADS MANUAL
CULVERTS & SMALL BRIDGES
DRG.TITLE.
R.C.C. SLAB 1.5 M. UPTO 6.0 M. SPAN
WIDTH AT ROAD TOP 7.5 M.
PLATE NO.-7.09

Fig: 8.33

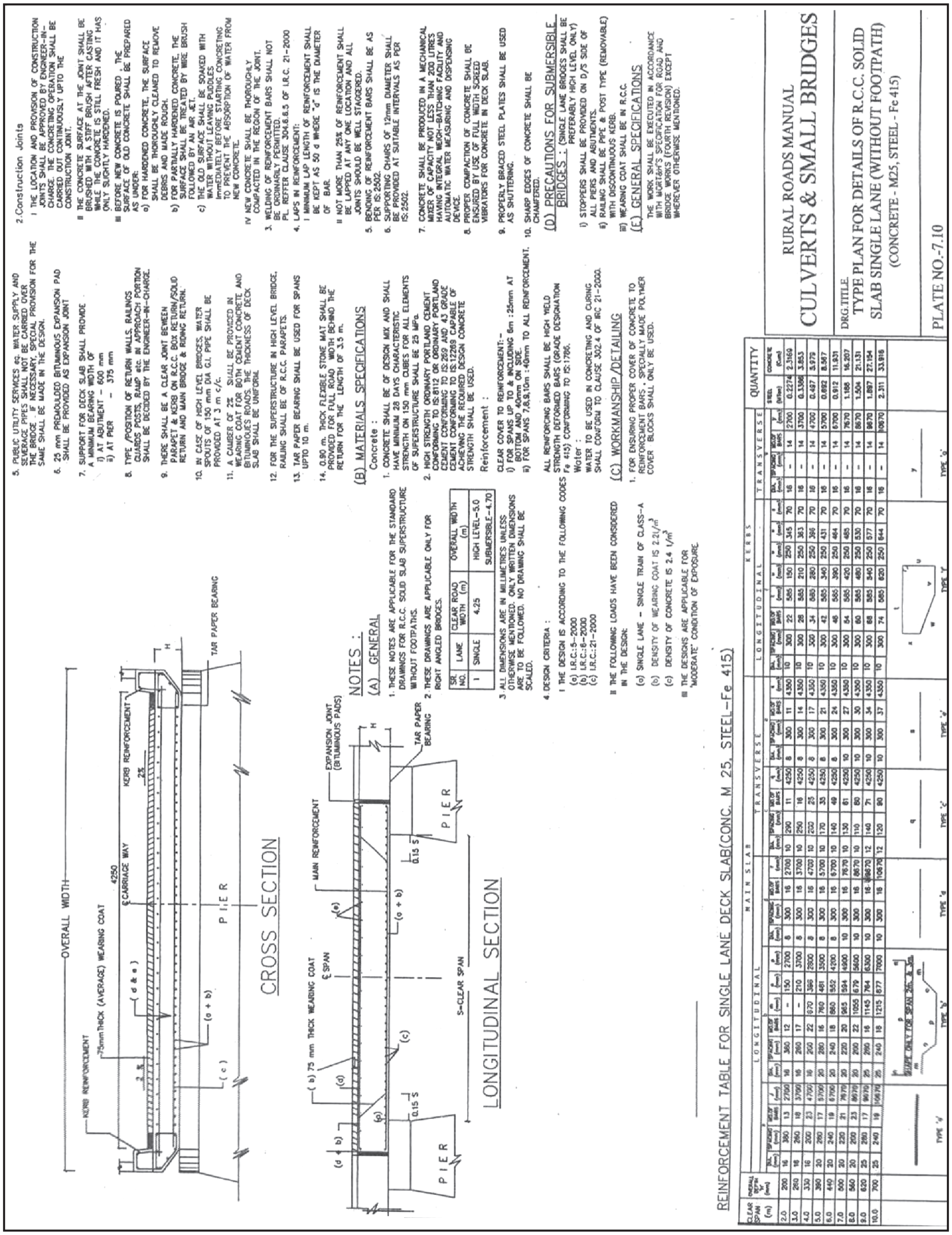

RURAL ROADS MANUAL
CULVERTS & SMALL BRIDGES
DRG.TITLE.
TYPE PLAN FOR DETAILS OF R.C.C. SOLID SLAB SINGLE LANE (WITHOUT FOOTPATH)
(CONCRETE - M25, STEEL - Fe 415)
PLATE NO.-7.10
CROSS SECTION
LONGITUDINAL SECTION
NOTES :
REINFORCEMENT TABLE FOR SINGLE LANE DECK SLAB(CONC. M 25, STEEL-Fe 415)

Fig: 8.34

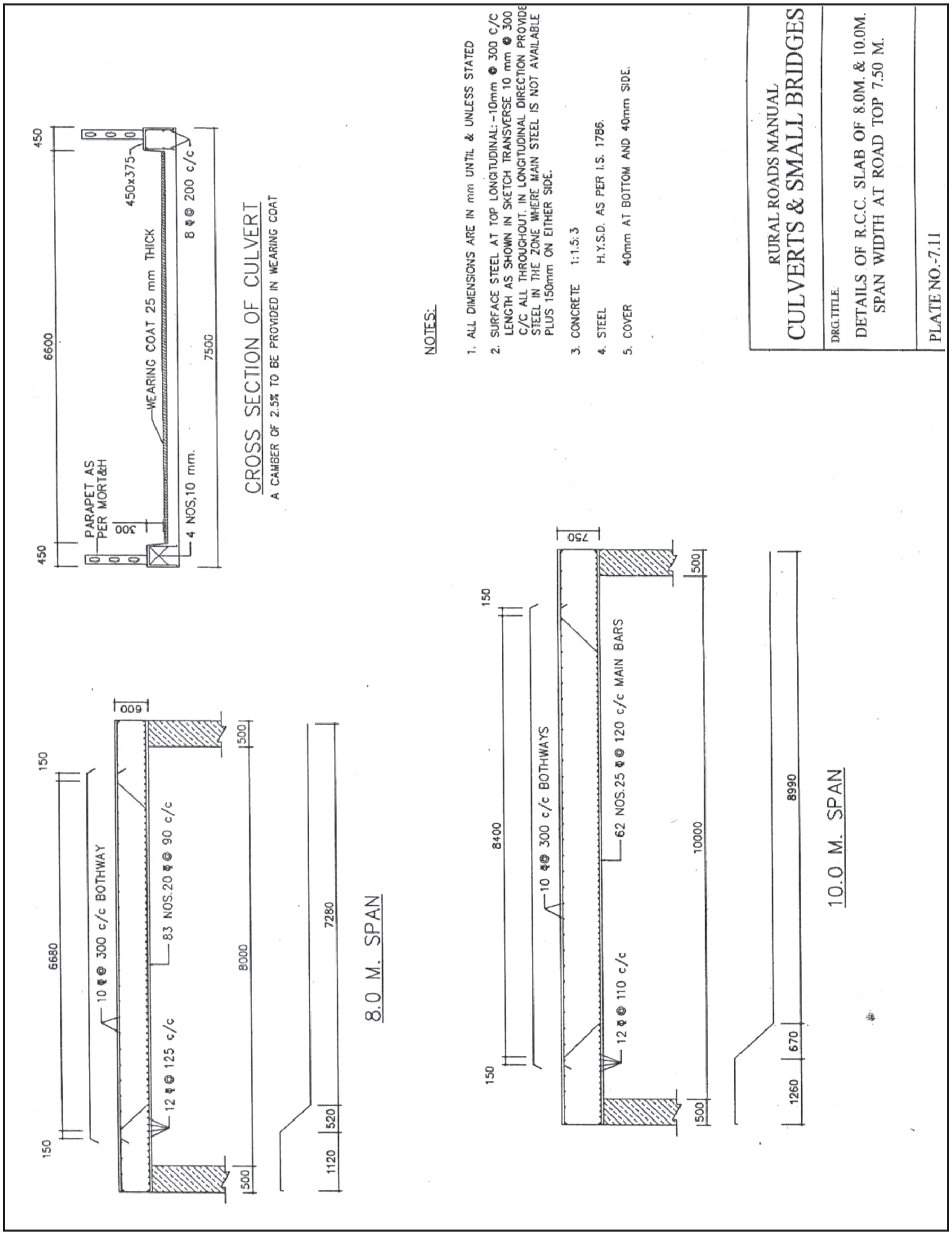

CROSS SECTION OF CULVERT
A CAMBER OF 2.5% TO BE PROVIDED IN WEARING COAT
450
6600
450
PARAPET AS PER MORT&H
300
WEARING COAT 25 mm THICK
450x375
4 NOS,10 mm.
8 ɸ @ 200 c/c
7500
NOTES:
1. ALL DIMENSIONS ARE IN mm UNTIL & UNLESS STATED
2. SURFACE STEEL AT TOP LONGITUDINAL:-10mm @ 300 C/C LENGTH AS SHOWN IN SKETCH TRANSVERSE 10 mm @ 300 C/C ALL THROUGHOUT. IN LONGITUDINAL DIRECTION PROVIDE STEEL IN THE ZONE WHERE MAIN STEEL IS NOT AVAILABLE PLUS 150mm ON EITHER SIDE.
3. CONCRETE 1:1.5:3
4. STEEL H.Y.S.D. AS PER I.S. 1786.
5. COVER 40mm AT BOTTOM AND 40mm SIDE.
RURAL ROADS MANUAL
CULVERTS & SMALL BRIDGES
DRG.TITLE.
DETAILS OF R.C.C. SLAB OF 8.0M. & 10.0M. SPAN WIDTH AT ROAD TOP 7.50 M.
PLATE NO.-7.11
150
6680
150
10 ɸ @ 300 c/c BOTHWAY
83 NOS.20 ɸ @ 90 c/c
12 ɸ @ 125 c/c
600
500
8000
500
1120
520
7280
8.0 M. SPAN
150
8400
150
10 ɸ @ 300 c/c BOTHWAYS
62 NOS.25 ɸ @ 120 c/c MAIN BARS
12 ɸ @ 110 c/c
750
500
10000
500
1260
670
8990
10.0 M. SPAN

Fig: 8.35

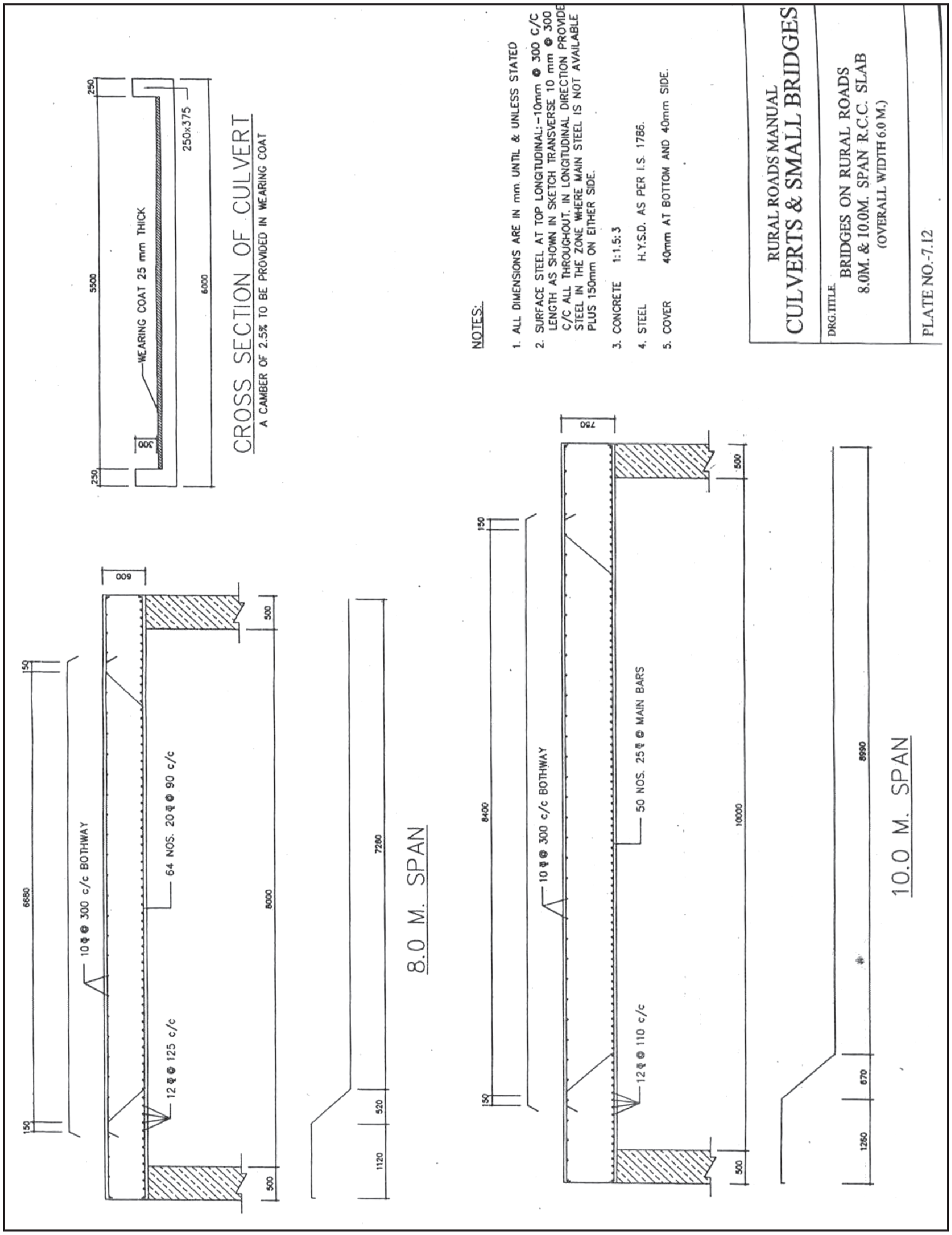

RURAL ROADS MANUAL
CULVERTS & SMALL BRIDGES
DRG.TITLE.
BRIDGES ON RURAL ROADS
8.0M. & 10.0M. SPAN R.C.C. SLAB
(OVERALL WIDTH 6.0 M.)
PLATE NO.-7.12
NOTES:
1. ALL DIMENSIONS ARE IN mm UNTIL & UNLESS STATED
2. SURFACE STEEL AT TOP LONGITUDINAL:-10mm @ 300 C/C LENGTH AS SHOWN IN SKETCH TRANSVERSE 10 mm @ 300 C/C ALL THROUGHOUT. IN LONGITUDINAL DIRECTION PROVIDE STEEL IN THE ZONE WHERE MAIN STEEL IS NOT AVAILABLE PLUS 150mm ON EITHER SIDE.
3. CONCRETE 1:1.5:3
4. STEEL H.Y.S.D. AS PER I.S. 1786.
5. COVER 40mm AT BOTTOM AND 40mm SIDE.
CROSS SECTION OF CULVERT
A CAMBER OF 2.5% TO BE PROVIDED IN WEARING COAT
WEARING COAT 25 mm THICK
250x375
5500
6000
250
300
8.0 M. SPAN
10 φ @ 300 c/c BOTHWAY
64 NOS. 20 φ @ 90 c/c
12 φ @ 125 c/c
6680
150
8000
7280
1120
520
500
600
10.0 M. SPAN
10 φ @ 300 c/c BOTHWAY
50 NOS. 25 φ @ MAIN BARS
12 φ @ 110 c/c
8400
150
10000
8990
1260
670
500
750

Fig: 8.36

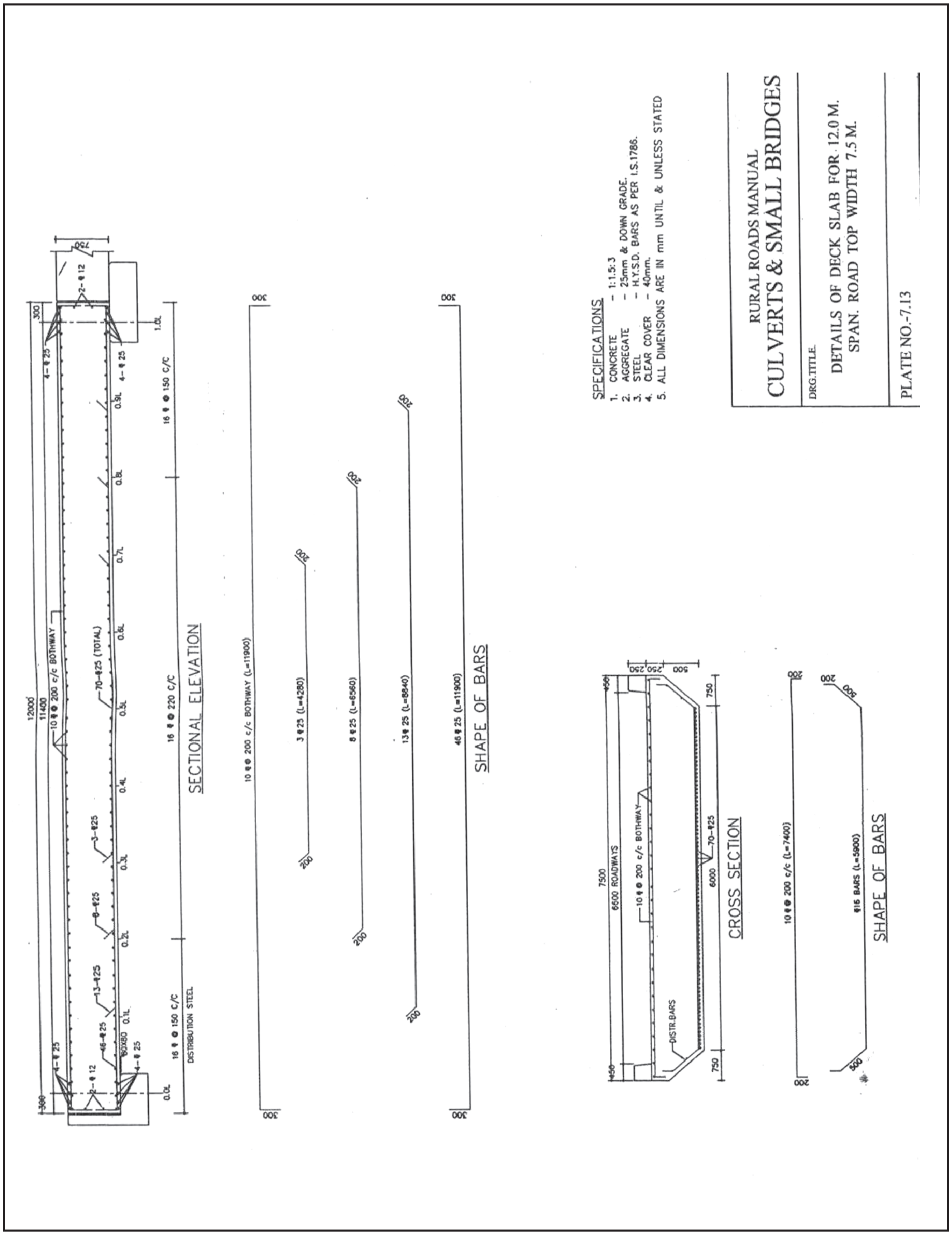

RURAL ROADS MANUAL
CULVERTS & SMALL BRIDGES
DRG.TITLE
DETAILS OF DECK SLAB FOR 12.0 M. SPAN. ROAD TOP WIDTH 7.5 M.
PLATE NO.-7.13
SPECIFICATIONS
1. CONCRETE - 1:1.5:3
2. AGGREGATE - 25mm & DOWN GRADE.
3. STEEL - H.Y.S.D. BARS AS PER I.S.1786.
4. CLEAR COVER - 40mm.
5. ALL DIMENSIONS ARE IN mm UNTIL & UNLESS STATED
SECTIONAL ELEVATION
SHAPE OF BARS
CROSS SECTION
SHAPE OF BARS

Fig: 8.37

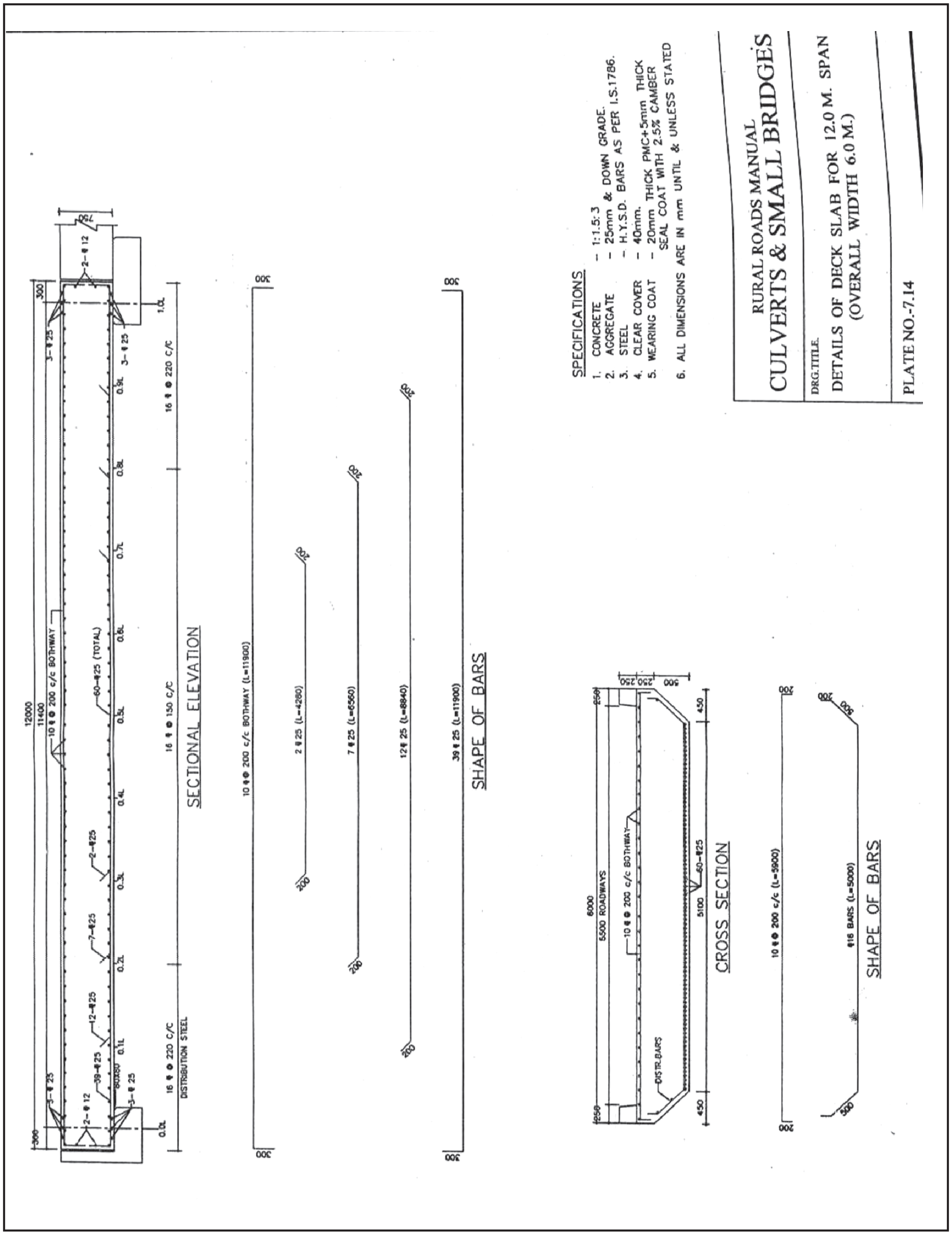

SECTIONAL ELEVATION
SHAPE OF BARS
CROSS SECTION
SHAPE OF BARS
SPECIFICATIONS
1. CONCRETE - 1:1.5:3
2. AGGREGATE - 25mm & DOWN GRADE.
3. STEEL - H.Y.S.D. BARS AS PER I.S.1786.
4. CLEAR COVER - 40mm.
5. WEARING COAT - 20mm THICK PMC+5mm THICK SEAL COAT WITH 2.5% CAMBER
6. ALL DIMENSIONS ARE IN mm UNTIL & UNLESS STATED
RURAL ROADS MANUAL
CULVERTS & SMALL BRIDGES
DRG.TITLE.
DETAILS OF DECK SLAB FOR 12.0 M. SPAN (OVERALL WIDTH 6.0 M.)
PLATE NO.-7.14

Fig: 8.38

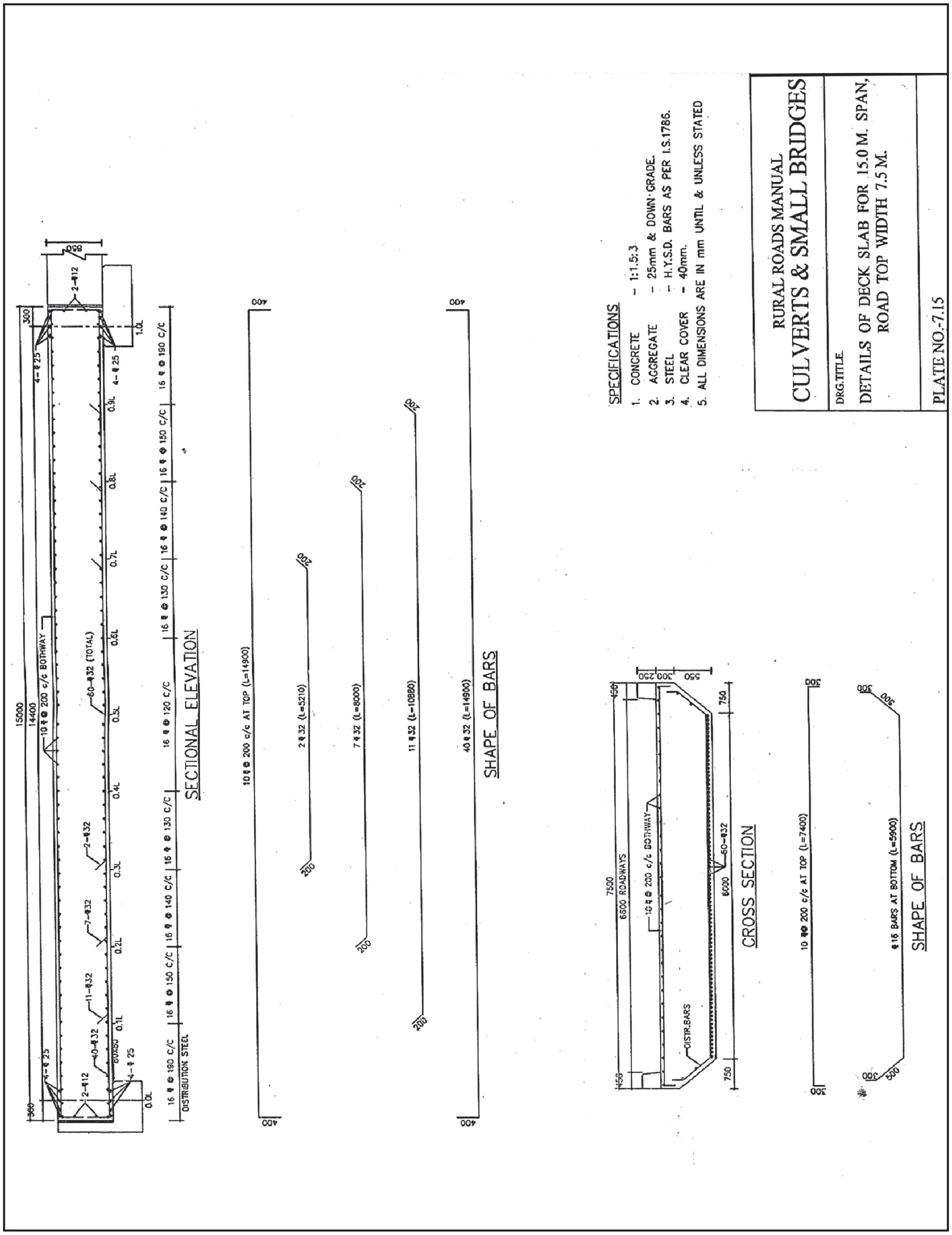

SECTIONAL ELEVATION
SHAPE OF BARS
CROSS SECTION
SHAPE OF BARS
SPECIFICATIONS
1. CONCRETE - 1:1.5:3
2. AGGREGATE - 25mm & DOWN GRADE.
3. STEEL - H.Y.S.D. BARS AS PER I.S.1786.
4. CLEAR COVER - 40mm.
5. ALL DIMENSIONS ARE IN mm UNTIL & UNLESS STATED
RURAL ROADS MANUAL
CULVERTS & SMALL BRIDGES
DRG.TITLE
DETAILS OF DECK SLAB FOR 15.0 M. SPAN, ROAD TOP WIDTH 7.5 M.
PLATE NO.-7.15

Fig: 8.39

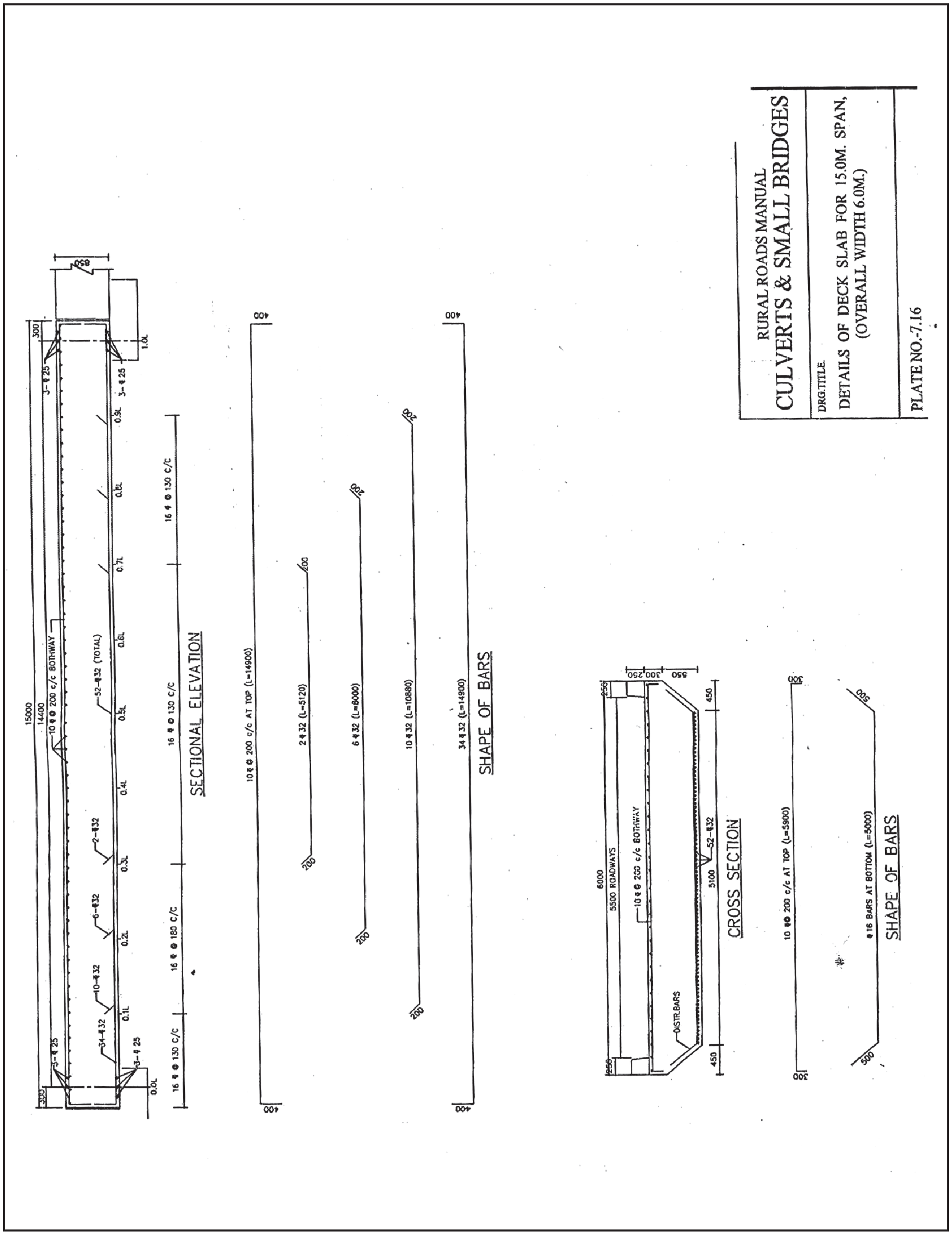

RURAL ROADS MANUAL
CULVERTS & SMALL BRIDGES
DRG.TITLE
DETAILS OF DECK SLAB FOR 15.0M. SPAN,
(OVERALL WIDTH 6.0M.)
PLATE NO.-7.16
SECTIONAL ELEVATION
SHAPE OF BARS
CROSS SECTION
SHAPE OF BARS

Fig: 8.40

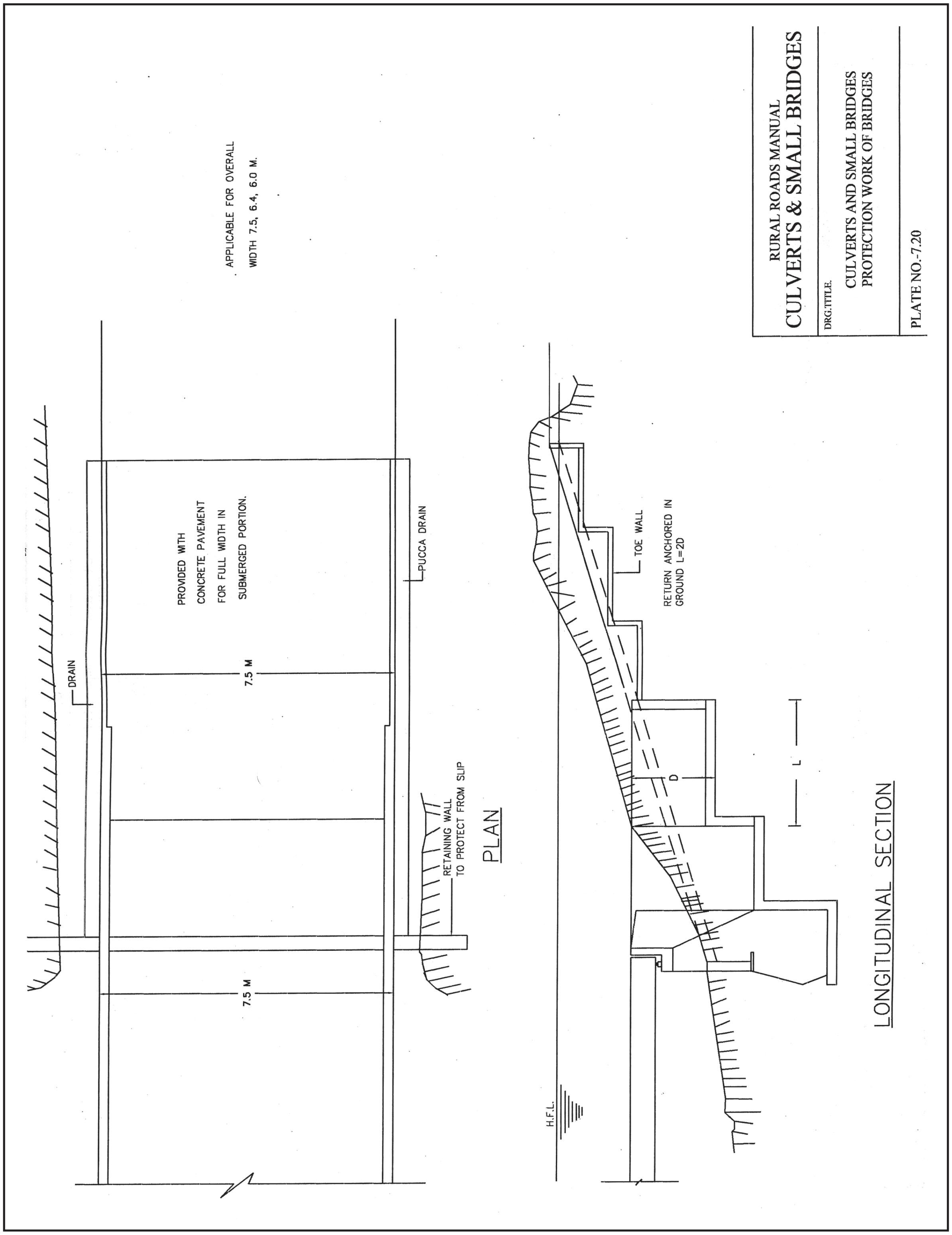

RURAL ROADS MANUAL
CULVERTS & SMALL BRIDGES
DRG.TITLE.
CULVERTS AND SMALL BRIDGES
PROTECTION WORK OF BRIDGES
PLATE NO.-7.20
APPLICABLE FOR OVERALL
WIDTH 7.5, 6.4, 6.0 M.
PROVIDED WITH
CONCRETE PAVEMENT
FOR FULL WIDTH IN
SUBMERGED PORTION.
PUCCA DRAIN
DRAIN
7.5 M
RETAINING WALL
TO PROTECT FROM SLIP
7.5 M
PLAN
TOE WALL
RETURN ANCHORED IN
GROUND L=2D
D
L
H.F.L.
LONGITUDINAL SECTION

Fig: 8.41

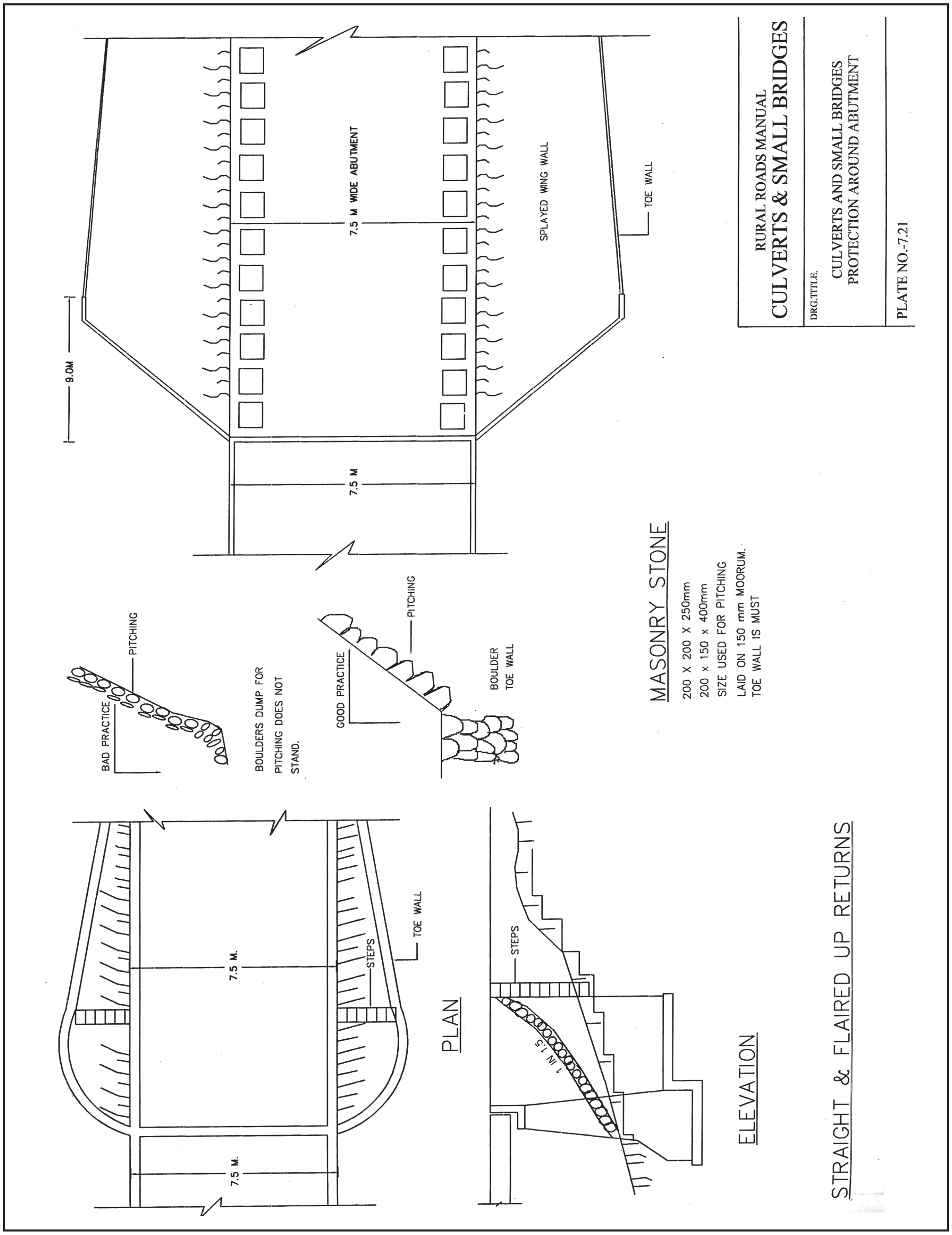

RURAL ROADS MANUAL
CULVERTS & SMALL BRIDGES
DRG.TITLE.
CULVERTS AND SMALL BRIDGES
PROTECTION AROUND ABUTMENT
PLATE NO.-7.21
7.5 M WIDE ABUTMENT
SPLAYED WING WALL
TOE WALL
9.0M
7.5 M
BAD PRACTICE
PITCHING
BOULDERS DUMP FOR
PITCHING DOES NOT
STAND.
GOOD PRACTICE
PITCHING
BOULDER
TOE WALL
MASONRY STONE
200 X 200 X 250mm
200 x 150 x 400mm
SIZE USED FOR PITCHING
LAID ON 150 mm MOORUM.
TOE WALL IS MUST
7.5 M.
STEPS
TOE WALL
7.5 M.
PLAN
STEPS
1 IN 1.5
ELEVATION
STRAIGHT & FLAIRED UP RETURNS

Fig: 8.42

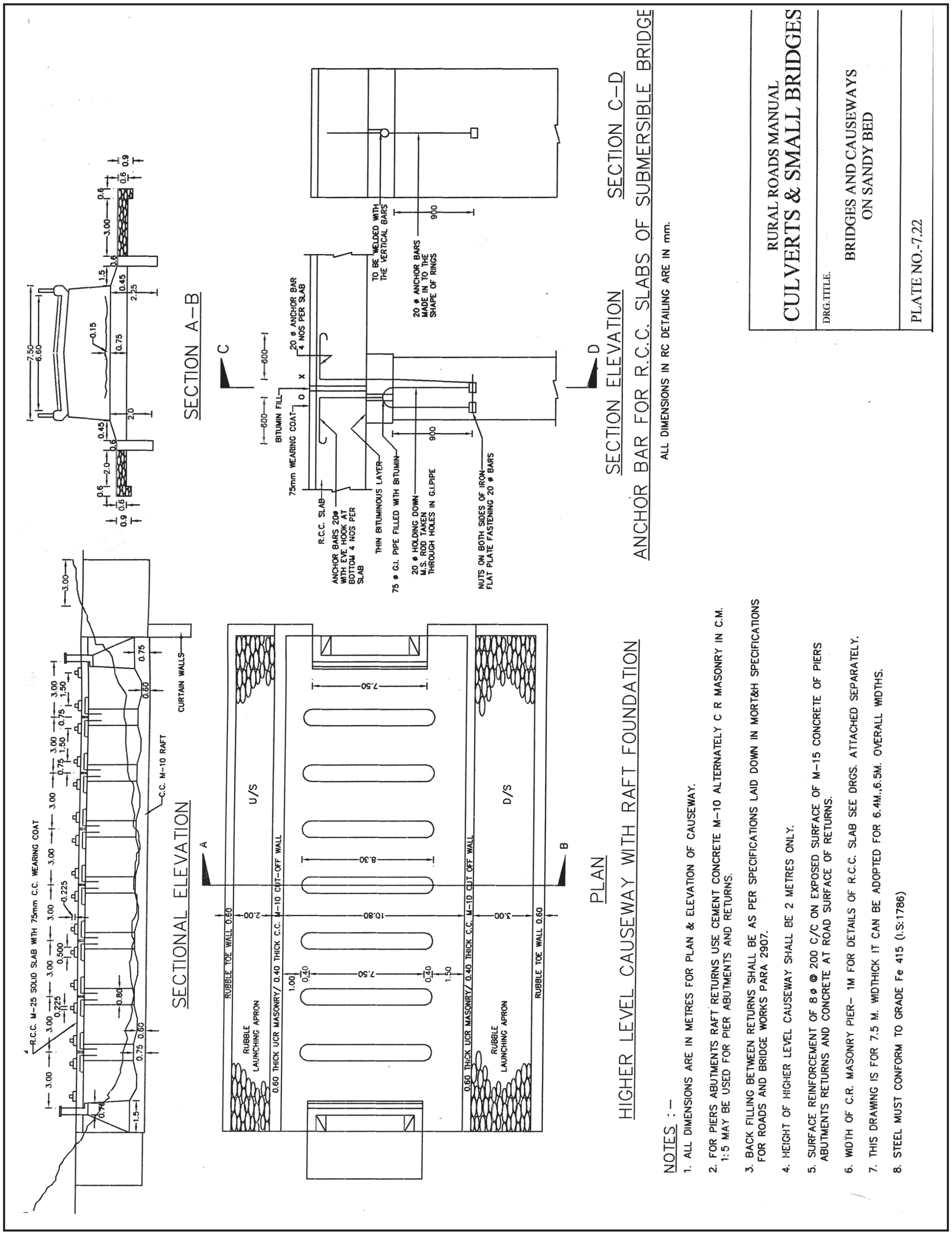
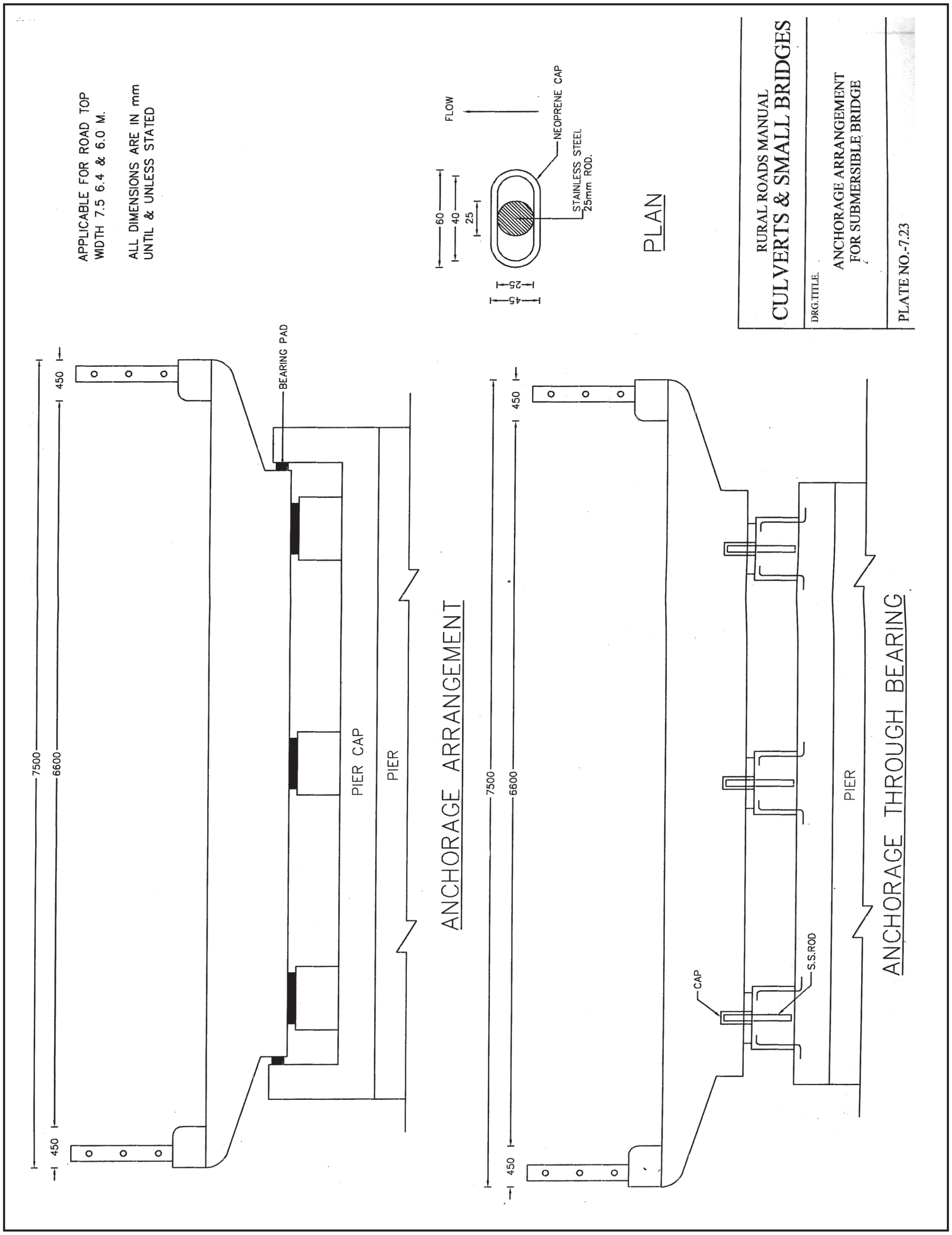

R.C.C. M-25 SOLID SLAB WITH 75mm C.C. WEARING COAT
C.C. M-10 RAFT
CURTAIN WALLS
SECTIONAL ELEVATION
SECTION A-B
RUBBLE TOE WALL 0.60
RUBBLE LAUNCHING APRON
U/S
0.60 THICK UCR MASONRY/ 0.40 THICK C.C. M-10 CUT-OFF WALL
D/S
PLAN
HIGHER LEVEL CAUSEWAY WITH RAFT FOUNDATION
BITUMIN FILL
75mm WEARING COAT
20 ø ANCHOR BAR 4 NOS PER SLAB
R.C.C. SLAB
ANCHOR BARS 20ø WITH EYE HOOK AT BOTTOM 4 NOS PER SLAB
THIN BITUMINOUS LAYER
75 ø G.I. PIPE FILLED WITH BITUMIN
20 ø HOLDING DOWN M.S. ROD TAKEN THROUGH HOLES IN G.I.PIPE
NUTS ON BOTH SIDES OF IRON FLAT PLATE FASTENING 20 ø BARS
TO BE WELDED WITH THE VERTICAL BARS
20 ø ANCHOR BARS MADE IN TO THE SHAPE OF RINGS
SECTION ELEVATION
SECTION C-D
ANCHOR BAR FOR R.C.C. SLABS OF SUBMERSIBLE BRIDGE
ALL DIMENSIONS IN RC DETAILING ARE IN mm.
NOTES :-
1. ALL DIMENSIONS ARE IN METRES FOR PLAN & ELEVATION OF CAUSEWAY.
2. FOR PIERS ABUTMENTS RAFT RETURNS USE CEMENT CONCRETE M-10 ALTERNATELY C R MASONRY IN C.M. 1:5 MAY BE USED FOR PIER ABUTMENTS AND RETURNS.
3. BACK FILLING BETWEEN RETURNS SHALL BE AS PER SPECIFICATIONS LAID DOWN IN MORT&H SPECIFICATIONS FOR ROADS AND BRIDGE WORKS PARA 2907.
4. HEIGHT OF HIGHER LEVEL CAUSEWAY SHALL BE 2 METRES ONLY.
5. SURFACE REINFORCEMENT OF 8 ø @ 200 C/C ON EXPOSED SURFACE OF M-15 CONCRETE OF PIERS ABUTMENTS RETURNS AND CONCRETE AT ROAD SURFACE OF RETURNS.
6. WIDTH OF C.R. MASONRY PIER- 1M FOR DETAILS OF R.C.C. SLAB SEE DRGS. ATTACHED SEPARATELY.
7. THIS DRAWING IS FOR 7.5 M. WIDTHICK IT CAN BE ADOPTED FOR 6.4M.,6.5M. OVERALL WIDTHS.
8. STEEL MUST CONFORM TO GRADE Fe 415 (I.S:1786)
RURAL ROADS MANUAL
CULVERTS & SMALL BRIDGES
DRG.TITLE.
BRIDGES AND CAUSEWAYS ON SANDY BED
PLATE NO.-7.22

Fig: 8.43



APPLICABLE FOR ROAD TOP WIDTH 7.5 6.4 & 6.0 M.
ALL DIMENSIONS ARE IN mm UNTIL & UNLESS STATED
FLOW
NEOPRENE CAP
STAINLESS STEEL 25mm ROD.
60
40
25
25
45
PLAN
RURAL ROADS MANUAL
CULVERTS & SMALL BRIDGES
DRG.TITLE.
ANCHORAGE ARRANGEMENT FOR SUBMERSIBLE BRIDGE
PLATE NO.-7.23
BEARING PAD
7500
6600
450
450
PIER CAP
PIER
ANCHORAGE ARRANGEMENT
7500
6600
450
450
CAP
S.S.ROD
PIER
ANCHORAGE THROUGH BEARING

Fig: 8.44

QUANTITIES OF MASONRY & P.C.C. IN ABUTMENT AND RETURN WALL.

HEIGHT OF ABUTMENT & RETURN ABOVE FOOTING (IN MTRS.)	QUANTITY IN ABUTMENT		RETURN			P.C.C. FOOTING		TOTAL QUANTITY OF MASONRY		TOTAL QUANTITY OF P.C.C.	CROSS SECTION AREA OF RETURN		
	MASONRY C.R. IN			MASONRY C.R. IN								MASONRY IN	
	C.M. 1:4 Cum.	C.M. 1:5 Cum.	LENGTH MTRS.	C.M.1:4 Cum.	C.M.1:5 Cum.	ABUTMENT Cum.	RETURN Cum.	C.M. 1:4 Cum.	C.M. 1:5 Cum.		P.C.C. FOOTING	C.M. 1:4 Sq.m.	C.M. 1:5 Sq.m.
3.00	27.84	19.94	3.00	22.62	11.86	6.16	4.20	50.46	31.80	10.36	0.385	1.998	1.050
3.50	35.44	25.30	3.00	23.52	16.24	6.46	4.46	58.96	41.54	10.92	0.420	2.219	1.532
4.00	37.82	34.38	3.00	24.22	20.99	6.78	4.80	62.04	55.37	11.58	0.450	2.459	2.129
4.50	40.08	44.14	3.00	27.08	28.25	9.04	5.26	67.16	72.39	14.30	0.485	2.697	2.183
5.00	48.76	62.86	4.00	40.68	51.38	10.30	7.74	89.44	114.24	18.04	0.623	3.380	4.270
6.00	69.42	87.32	4.00	66.56	86.30	10.48	11.12	135.98	173.62	21.60	0.712	4.500	5.980
7.00	74.70	103.04	4.00	83.28	115.36	10.74	13.48	157.98	218.40	24.22	0.800	5.760	7.940
8.00	102.30	138.86	4.00	111.90	158.50	11.90	14.90	214.20	297.36	26.80	0.890	7.200	10.200

QUANTITIES OF P.C.C. CAP & DIRTWALL FOR ABUTMENTS

SPAN IN MTRS.	P.C.C. IN Cu.m.	REINFORCEMENT K.G.
3.50	35.44	25.30
4.00	37.82	34.38
4.50	40.08	44.14
5.00	48.76	62.86
6.00	69.42	87.32
7.00	74.70	103.04
8.00	102.30	138.86

QUANTITIES OF R.C.C. DECK SLAB

CLEAR SPAN 1.50 M. TO 10.00 M.	CONCRETE m^3	STEEL Kg.
1.5	3.31	298
2.00	4.68	478
3.00	8.10	827
4.00	12.76	1273
5.00	18.70	1828
6.00	24.48	2592
7.00	40.50	2684
10.00	61.87	3684
SPANS M.	CONCRETE m^3	STEEL Kg.
12.00	63.00	4683
15.00	89.50	7253
PER METRE QUANTITIES OF KERB & WEARING COAT		
SPAN	CONCRETE m^3	STEEL Kg.
1.50 M TO 15.00 M.	0.83	54
12.00 M. TO 15.00 M.	0.72	44

NOTES :–

1. FOR INTERMEDIATE HEIGHTS IN EACH GROUP SAY BETWEEN 3.00 M. TO 3.50 M. THE QUANTITIES MAY BE WORKED FROM OFFSETS OF THE SECTION. THE QUANTITIES OF FOOTING MAY BE BY PROVIDING OFFSET OF 100mm ON EITHER SIDE OF MASONRY.
2. ONLY TWO LENGTHS OF THE RETURN WALLS ARE CONSIDERED i.e. 3.00 M. & 4.00 M. IN SOME CASES FOR HEIGHTS FROM 5.00 M. TO 8.00 M., THE LENGTH OF RETURN WALL IS LIKELY TO BE MORE THAN 4.00 M. SINCE THE LENGTH OF RETURN WALL IS 1.5 TIMES OF THE HEIGHT FROM BED LEVEL TO ROAD TOP LEVEL OF THE ABUTMENT: THE CROSS SECTIONAL AREA OF THE RETURN WALL ARE MENTIONED, THIS AREA x LENGTH OF RETURNS ON 4 SIDES WILL BE ADDED IN QUANTITIES OF MASONRY, BASE CONCRETE & COPING.
3. INSTEAD OF STONE MASONRY IF IT IS DECIDED TO PROVIDED P.C.C., THAN THE BATTER MAY BE PROVIDE IN PLACE OF STEPS.
4. THE SURFACE REINFORCEMENT IN P.C.C. CAP & DIRT WALL BE 8mm BARS AT 200mm C/C OR 4 Kg/m^2 ON EXPOSED FACES.
5. COPING IN RETURNS
   FOR 3.00 M. LENGTH = 1.61 cum.
   FOR 4.00 M. LENGTH = 2.31 cum.
   THE QUANTITY OF 150mm THICK COPING IS 0.06 cu.m. PER METRE LENGTH REINFORCEMENT IN COPING @ 4 Kg/m OF EXPOSED SURFACE AREA.
   FOR 3.00 M. LENGTH = 6.44 Kg.
   FOR 4.00 M. LENGTH = 9.24 Kg.
6. WASTAGE IN STEEL OF DECK SLAB MAY BE WITHIN 3%.

RURAL ROADS MANUAL
CULVERTS & SMALL BRIDGES

DRG.TITLE.
QUANTITIES OF ABUTMENTS, RETURNS & R.C.C. SLAB

PLATE NO.-7.24

Fig: 8.45

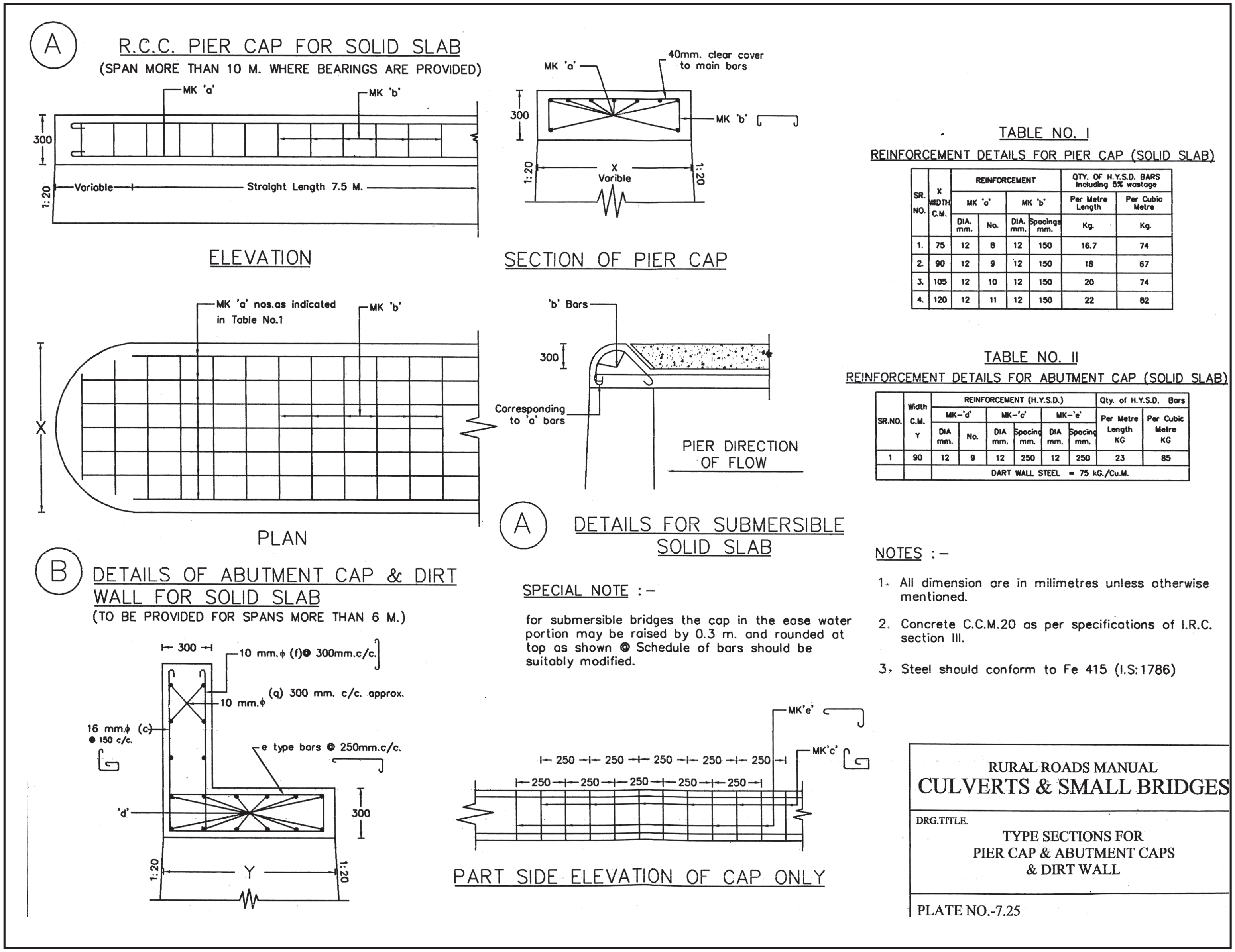


TABLE NO. I

REINFORCEMENT DETAILS FOR PIER CAP (SOLID SLAB)

SR. NO.	X WIDTH C.M.	REINFORCEMENT MK 'a' DIA. mm.	MK 'a' No.	MK 'b' DIA. mm.	MK 'b' Spacings mm.	QTY. OF H.Y.S.D. BARS Including 5% wastage Per Metre Length Kg.	Per Cubic Metre Kg.
1.	75	12	8	12	150	16.7	74
2.	90	12	9	12	150	18	67
3.	105	12	10	12	150	20	74
4.	120	12	11	12	150	22	82

TABLE NO. II

REINFORCEMENT DETAILS FOR ABUTMENT CAP (SOLID SLAB)

SR.NO.	Width C.M. Y	REINFORCEMENT (H.Y.S.D.) MK-'d' DIA mm.	MK-'d' No.	MK-'c' DIA mm.	MK-'c' Spacing mm.	MK-'e' DIA mm.	MK-'e' Spacing mm.	Qty. of H.Y.S.D. Bars Per Metre Length KG	Per Cubic Metre KG
1	90	12	9	12	250	12	250	23	85
		DART WALL STEEL = 75 KG./Cu.M.							

Fig: 8.46

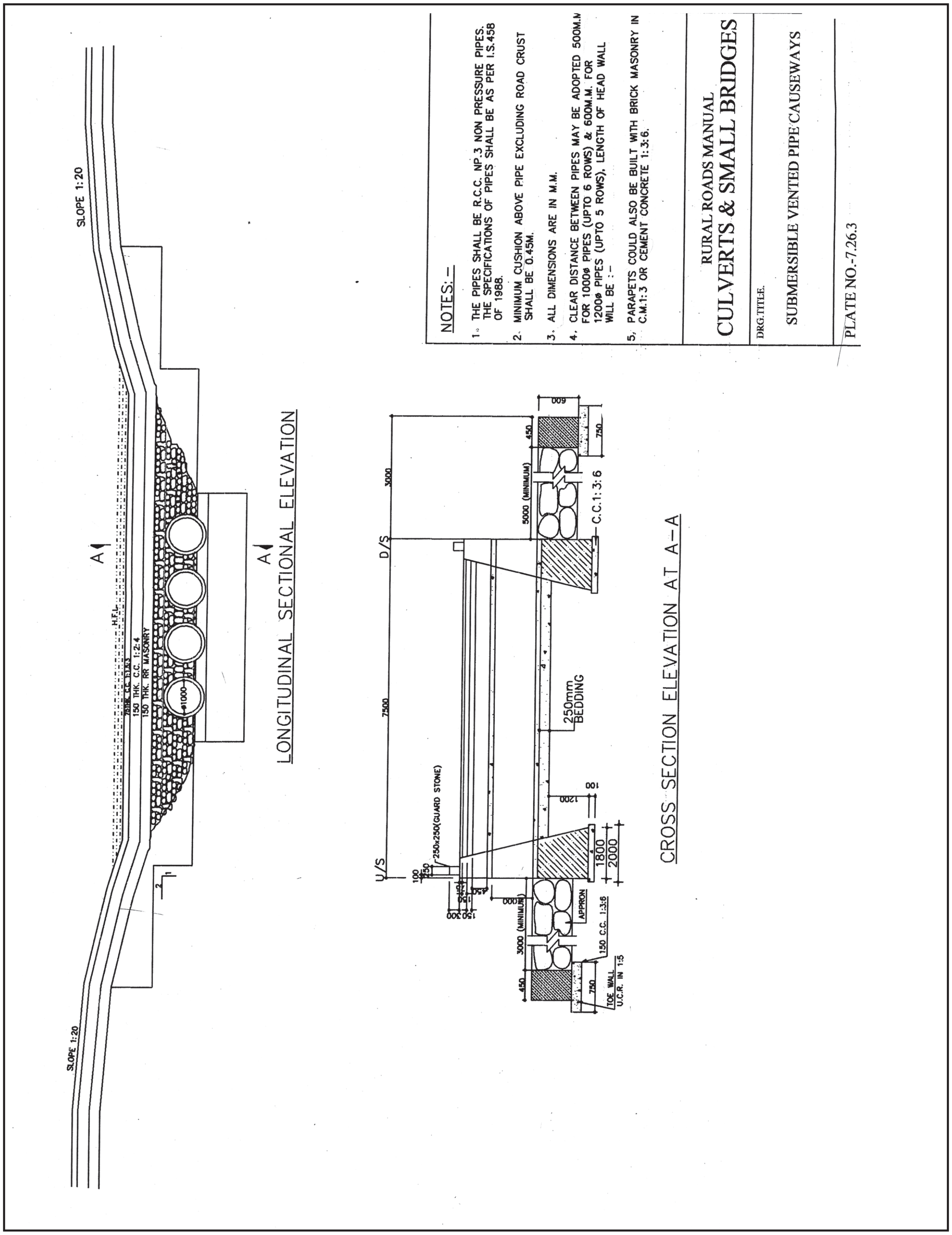

SLOPE 1:20
H.F.L.
150 THK. C.C. 1:2:4
150 THK. RR MASONRY
A
LONGITUDINAL SECTIONAL ELEVATION
U/S
D/S
250x250(GUARD STONE)
7500
3000
250mm BEDDING
APPRON
TOE WALL U.C.R. IN 1:5
150 C.C. 1:3:6
C.C.1:3:6
5000 (MINIMUM)
3000 (MINIMUM)
1800
2000
CROSS SECTION ELEVATION AT A-A
NOTES:-
1. THE PIPES SHALL BE R.C.C. NP.3 NON PRESSURE PIPES. THE SPECIFICATIONS OF PIPES SHALL BE AS PER I.S.458 OF 1988.
2. MINIMUM CUSHION ABOVE PIPE EXCLUDING ROAD CRUST SHALL BE 0.45M.
3. ALL DIMENSIONS ARE IN M.M.
4. CLEAR DISTANCE BETWEEN PIPES MAY BE ADOPTED 500M.M FOR 1000ø PIPES (UPTO 6 ROWS) & 600M.M. FOR 1200ø PIPES (UPTO 5 ROWS), LENGTH OF HEAD WALL WILL BE :-
5. PARAPETS COULD ALSO BE BUILT WITH BRICK MASONRY IN C.M.1:3 OR CEMENT CONCRETE 1:3:6.
RURAL ROADS MANUAL
CULVERTS & SMALL BRIDGES
DRG.TITLE.
SUBMERSIBLE VENTED PIPE CAUSEWAYS
PLATE NO.-7.26.3

Fig: 8.47

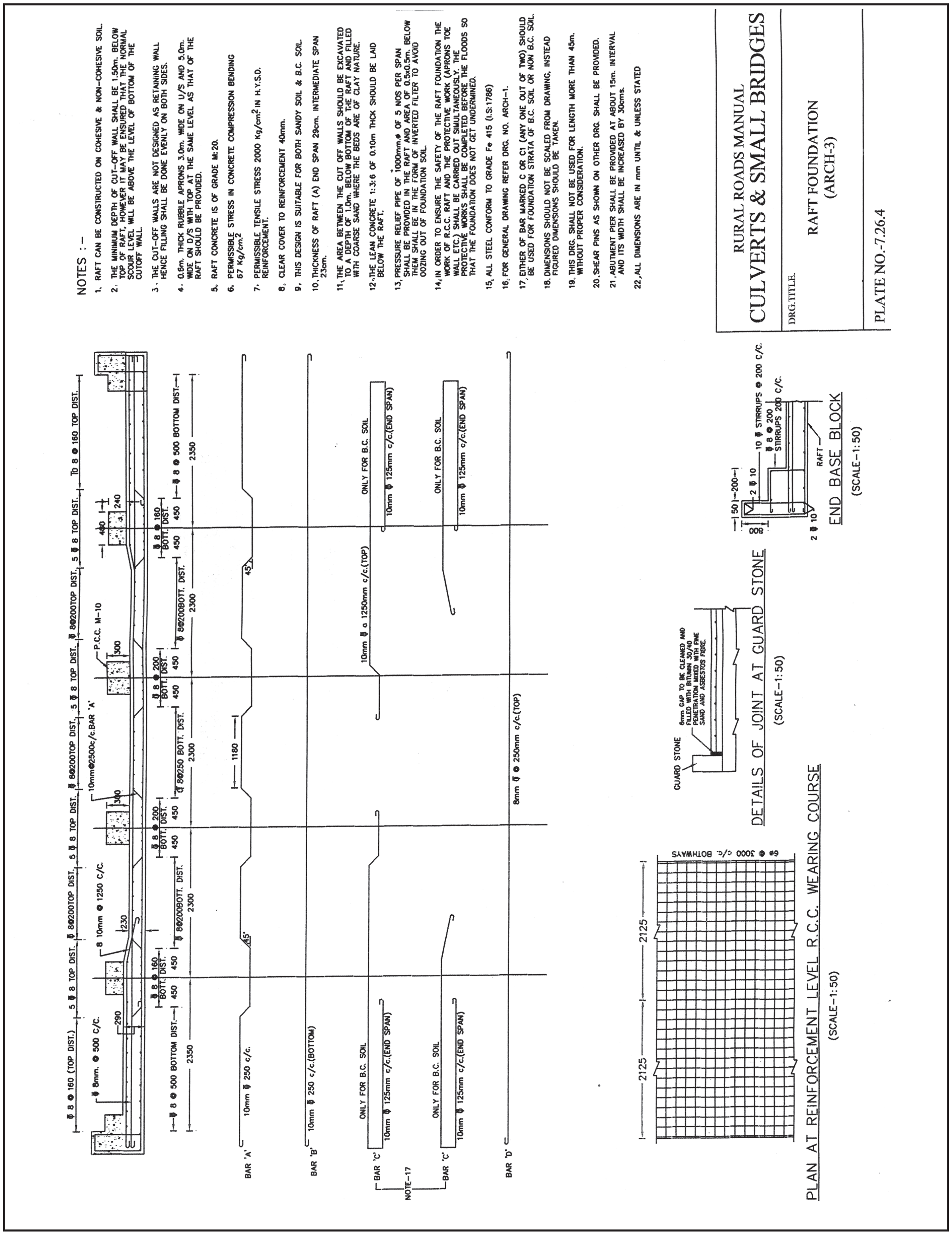

RURAL ROADS MANUAL
CULVERTS & SMALL BRIDGES
DRG.TITLE.
RAFT FOUNDATION
(ARCH-3)
PLATE NO.-7.26.4
NOTES :-
PLAN AT REINFORCEMENT LEVEL R.C.C. WEARING COURSE
(SCALE-1:50)
DETAILS OF JOINT AT GUARD STONE
(SCALE-1:50)
END BASE BLOCK
(SCALE-1:50)
BAR 'A'
BAR 'B'
BAR 'C'
BAR 'D'
NOTE-17
ONLY FOR B.C. SOIL
GUARD STONE
2125

Fig: 8.48

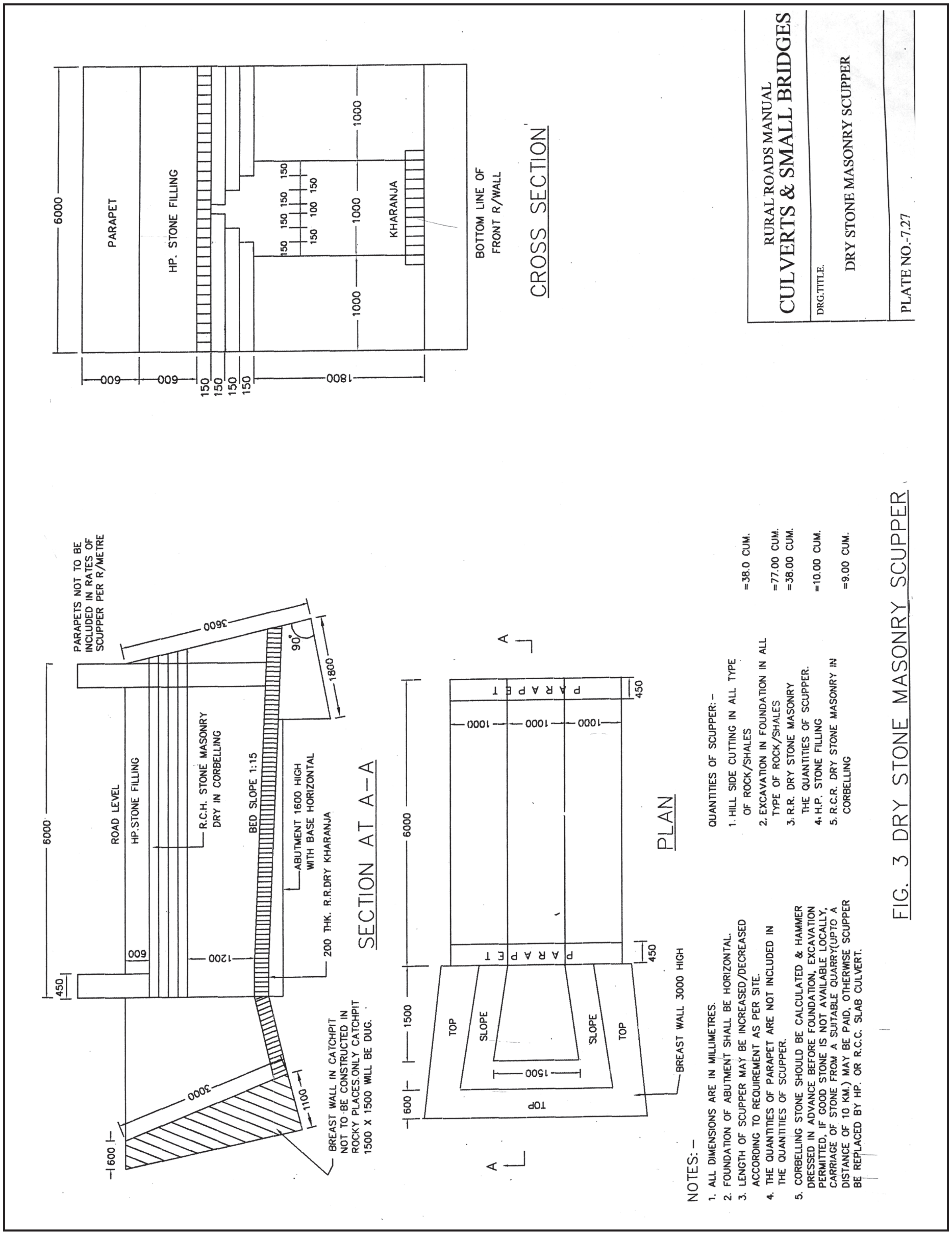

PARAPET
HP. STONE FILLING
KHARANJA
BOTTOM LINE OF FRONT R/WALL
CROSS SECTION
PARAPETS NOT TO BE INCLUDED IN RATES OF SCUPPER PER R/METRE
ROAD LEVEL
HP.STONE FILLING
R.C.H. STONE MASONRY DRY IN CORBELLING
BED SLOPE 1:15
ABUTMENT 1600 HIGH WITH BASE HORIZONTAL
200 THK. R.R.DRY KHARANJA
BREAST WALL IN CATCHPIT NOT TO BE CONSTRUCTED IN ROCKY PLACES.ONLY CATCHPIT 1500 X 1500 WILL BE DUG.
SECTION AT A-A
PARAPET
TOP
SLOPE
BREAST WALL 3000 HIGH
PLAN
NOTES:-
1. ALL DIMENSIONS ARE IN MILLIMETRES.
2. FOUNDATION OF ABUTMENT SHALL BE HORIZONTAL.
3. LENGTH OF SCUPPER MAY BE INCREASED/DECREASED ACCORDING TO REQUIREMENT AS PER SITE.
4. THE QUANTITIES OF PARAPET ARE NOT INCLUDED IN THE QUANTITIES OF SCUPPER.
5. CORBELLING STONE SHOULD BE CALCULATED & HAMMER DRESSED IN ADVANCE BEFORE FOUNDATION, EXCAVATION PERMITTED, IF GOOD STONE IS NOT AVAILABLE LOCALLY, CARRIAGE OF STONE FROM A SUITABLE QUARRY(UPTO A DISTANCE OF 10 KM.) MAY BE PAID, OTHERWISE SCUPPER BE REPLACED BY HP. OR R.C.C. SLAB CULVERT.
QUANTITIES OF SCUPPER:-
1. HILL SIDE CUTTING IN ALL TYPE OF ROCK/SHALES =38.0 CUM.
2. EXCAVATION IN FOUNDATION IN ALL TYPE OF ROCK/SHALES =77.00 CUM.
3. R.R. DRY STONE MASONRY THE QUANTITIES OF SCUPPER. =38.00 CUM.
4. H.P. STONE FILLING =10.00 CUM.
5. R.C.R. DRY STONE MASONRY IN CORBELLING =9.00 CUM.
FIG. 3 DRY STONE MASONRY SCUPPER
RURAL ROADS MANUAL
CULVERTS & SMALL BRIDGES
DRG.TITLE.
DRY STONE MASONRY SCUPPER
PLATE NO.-7.27

Fig: 8.49

The Investigation and Formulation of Proposal for Concrete Bridges and the design of the same are governed by the following IRC/IS codes/references and other relevant literature.

1.	IRC : SP : 54-2000	-	Project Preparation Manual for Bridges
2.	MORT&H Pocket Book for Bridge Engineers (2000)		
3.	IRC : 5 : 1998 Sec - I	-	General features of design
4.	IRC : 6 : 2000 Sec - II	-	Loads and stresses
5.	IRC : 21 :2000 (Sec.III)	-	Standard specification and code of practice for Road Bridges, Sec - III, Cement Concrete. (Plain and Reinforced)
6.	IRC : 18 : 2000	-	Design criteria for prestressed concrete Road Bridges (Post tensioned concrete)
7.	IRC : 22 - 1986 (Sec VI)	-	Composite construction
8.	IRC : 78 - 2000, (Sec VII)	-	Foundation and substructure
9.	IRC : 83 - 1999 Part I	-	Metallic Bearings
	IRC : 83 - 1987 Part II	-	Elastomeric Barings
	IRC : 83 - 2002 Part III	-	Pot, Pot cum PTFE, Pin and Metallic guide bearings
10.	IRC : SP : 13 - 2004	-	Guidelines for design of small bridges and culverts
11.	IS 6403 - 1981	-	Bearing capacity of shallow foundation
12.	IS 2911 - Part-1, Sec - II	-	Bored, cast-in-situ concrete piles.
13.	IS 2911 - Part-IV	-	Load test on piles
14.	IRC special publication	-	Design and construction practice of Submersible bridges and causeway in India

15. MORT&H Pocket Book for Bridges, Fourth Revision

16. IRC: 73 - 1980 - Geometric Design standards for rural (Non - urban) Highways

17. IRC: 38 - 1988 - Guidelines for design of curves for Highways and design Tables

18. Civil Engineers Hand Book by khanna

19. IRC: 89 - 1997 - Guidelines for design and Construction of River Training and Control works for road Bridges.

20. IRC: 86 - 1983 - Geometric design standards for Urban Roads in plains

8.15. PROTECTIVE WORKS

8.15.1. RETAINING WALLS

The wall used to retain some material on one or both sides of it can be termed as retaining wall. The materials to be retained on either side may be different. Retaining walls are mostly used for roads in hilly areas, swimming pools, at the ends of the bridges in the form of abutments, constructing a building on a site where filling is required and under-ground water tanks.

Earth retaining structures are retaining walls, sheet piling, bulk heads, basement walls, and other permanent and temporary structures used in earthworks and foundation engineering that retain vertical or almost vertical slopes of earth masses.

According to the strength and service required, retaining walls may be constructed of

i. Rough Dry stone masonry with concrete foundation if necessary,

ii. Rough Dry stone masonry with strengthening bands of Stone in cement,

iii. Masonry in cement mortar on cement concrete foundation.

Retaining walls up to about 4 metre height should generally be in Random Rubble masonry, walls from 4 to 8 metre in RR Dry masonry with 1:6 cement masonry bands or with a course of Cement concrete 1:4:8 throughout the section both in lengthwise and breadth wise directions of retaining wall to break the joints and to cover up short-comings in execution of dry retaining wall. Beyond 8 metre height walls should be avoided and when unavoidable these should be stepped and built in cement mortar.

Retaining walls in RR dry stone masonry with proper bond stones can be safely be constructed up to 4 m height. Bond stones should be provided at least one set per 0.50 sq. metre of wall face. They should overlap each other by at least 15cm.

8.15.2. FORCES ACTING ON EARTH RETAINING STRUCTURES

The common forces acting on the earth pressures encountered are:

a. Weight of the wall.

b. Lateral earth pressure.

c. Vertical loads on the wall.

d. Wind pressure.

e. Horizontal loads on the wall.

f. Hydrostatic pressure of water.

g. Hydrostatic uplift.

h. Pore water pressure.

i. Seepage forces.

8.15.3. TYPES OF RETAINING WALLS

The various types of retaining walls are described below:

a. Gravity type retaining wall.

b. Semi-gravity retaining wall.

c. T-shaped Cantilever wall.

d. L-shaped retaining wall.

e. Reversed L-shaped retaining wall.

f. Basement wall.

g. Counterfort retaining wall.

h. Buttressed retaining wall.

Gravity retaining walls are constructed with plain concrete or stone masonry. These walls depend on their own weight and any soil resting on the masonry for their stability. This type of construction is not very economical for high walls.

In many cases, a small amount of steel may be used for the construction of gravity wall, thereby minimizing the size of the wall sections. Such walls are generally referred to as semi-gravity walls.

Cantilever retaining walls are made of reinforced concrete that consists of a thin stem and a base slab. This type of wall is economical up to a height of 8m.In this type, T-shaped, L-shaped and reverse L-shaped cantilever retaining wall are used.

Counterfort retaining walls are similar to cantilever walls except for the fact that, at regular intervals, they have thin vertical concrete slabs known as counterforts

that tie the wall and the base slab together. The purpose of the counterforts is to reduce shear and the bending moments.

8.15.4. STABILITY OF RETAINING WALLS

A retaining wall may fail in any of the following ways:

1. It may overturn about its toe.
2. It may slide along its base.
3. It may fail due to the loss of bearing capacity of the soil supporting the base.
4. It may undergo deep-seated shear failure.
5. It may fail through excessive settlement.

8.15.5. CONSTRUCTION JOINTS

A retaining wall may be constructed with one or more of the following joints.

1. **Construction joints** are vertical and horizontal joints that are placed between two successive pours of concrete. To increase the shear at the joints, keys may be used. If keys are not used, the surface of the first pour is cleaned and roughened before the next pour of concrete.
2. **Contraction joints** are vertical joints placed in the face of a wall that allow the concrete to shrink without noticeable harm. The grooves may be about 6 to 8 mm wide and 12 to 16 mm deep.
3. **Expansion joints** allow for the expansion of concrete caused by temperature changes; vertical expansion joints from the base to the top of the wall may also be used. These joints may be filled with flexible joint fillers. In most cases, horizontal reinforcing steel bars running across the stem are continuous through all joints. The steel is greased to allow the concrete to expand.

8.15.6. GENERAL DESIGN REQUIREMENTS

The following requirements should be satisfied by a retaining wall in order to avoid its failure.

1. The thickness of different components of the retaining wall, i.e. stem, heel and toe should be sufficient to resist the moments, shear forces acting on the wall.

2. The factor of safety against sliding should be at least 1.5 and not more than 2.0 in any case.

3. The factor of safety against overturning should be at least 1.5.

4. The bearing pressure at toe should be less than the bearing capacity of the soil.

5. If the length of the retaining wall exceeds 45 m, then the expansion joint should be provided. The spacing of such joints would depend upon the temperature variation, exposure to weather and the season of laying concrete. Flexible joint filler 12 mm to 20 mm thick is placed in the staggered form.

6. A construction joint, capable of resisting the shear force caused by the lateral earth pressures, should be provided between the base slab and stem of retaining wall. This joint consists of a key and dowel bars.

A: Check for Overturning

The factor of safety against overturning about the toe that is, about point C may be expressed as,

$$\text{FS (overturning)} = \frac{\Sigma M_r}{\Sigma M_o}$$

Where:

ΣM_o = Sum of the moments of forces tending to overturn about point C
ΣM_r= Sum of the moments of forces tending to resist overturning about point C.

$$\text{FS (sliding)} = \frac{\Sigma F_r}{\Sigma F_d}$$

Where:

Σ Fr = Sum of the horizontal resisting forces.
Σ Fd = Sum of the horizontal driving forces.

8.15.7. Design:

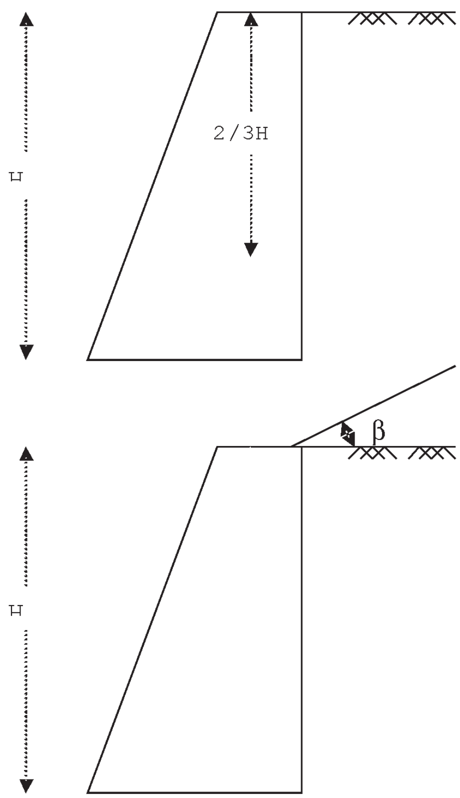
Principles of Design: The principal cause of failure of a retaining wall.

a. Overturning,

b. Tension in Masonry,

c. Sliding and

d. Pressure on Foundations.



Overturning: For safety against overturning, the resultant (R) of the horizontal and vertical forces must pass through middle third of the base of the wall.

Tension in masonry: To avoid tension in masonry, the resultant should pass through middle third of the base of the retaining wall. This can be checked by taking moments about the toe of the wall. The Earth pressure (P) can be computed by using the following formulae for vertical backed wall.

a. Without surcharge.

$$\mathbf{P = \gamma H^2 (1-\sin\phi)/ (1+\sin\phi)}$$

Where; P = Earth Pressure acting at depth of 2/3 H below the horizontal earth surface,

γ = Unit weight of Earth in Kg/m3,

ϕ = Angle of repose of soil,

H = Total height of wall.

b. With surcharge (angle of surcharge = β)

$$P = Ka\, \gamma\, H^2 / 2$$

Where; Ka = Co-efficient of Active Earth pressure

$$= \frac{\cos\beta \quad x \sqrt{(\cos\beta \quad - \cos^2\beta \quad - \cos^2\phi}}{\sqrt{(\cos\beta \quad + \cos^2\beta \quad - \cos^2\phi}}$$

Sliding: The walls must have a factor of safety of 2.0 against sliding.

Pressure on Foundations: The pressure on foundation material at the toe of the wall must not be greater than the safe working stress. By projecting the toe, the centre of the base is brought nearer to the resultant and the toe pressure is reduced.

The average pressure on the foundations

Pa = Total vertical force / Width of base.

Depth of Foundations: Foundations must be taken deep enough to reach solid material, and be safe from frost action, surface water and scour. The actual depth is dependent on the nature of soil and may be 0.30 to 0.90 m.

Practical proportions: For average dry conditions, width of base may be taken as 0.4 H + 0.30 m (where, H is the total height of wall in m) and width of foundation footing as 0.5 H + 0.30 m. Top thickness of the wall is generally kept as 0.60m, Minimum depth of foundation as 0.1 H + 0.30 m and the projection of any footing course not exceeding half the depth of the course. Back is generally vertical and front batter about 1 in 4.

In case of loose ground, the walls are generally 0.90 m thick at top with front batter about 1in 3, back may be vertical or given a batter of 1 to 5 to reduce the masonry work.

Parapets: For defining the edge of road and safety of traffic, parapets are required. They are usually made of 0.45m thick of stone masonry in lengths of 2 m to 6 m with 0.6 m to 1.0 m gaps. Their height usually 0.6 m and follow regular geometrical edge of road.

Construction :

Foundations: Foundations must be taken deep enough to rest on sound foundation materials, which must be safe from scour, frost and surface water. Rock must be cut in level steps or to a downward slope towards the filling. Rock bed slope should be towards the hill and not away. The filling foundation pits in front of toe of the retaining wall up to ground level should be done to avoid pooling of water leading to toe erosion.

Walls - Masonry construction: The base width must be substantial and capable of distributing the pressure over the foundation. The projections of any footing course should not exceed half the depth of the course. The top thickness is usually 0.60m. The front batter may be 1 in 3 up to 4 metre height and there after made flatter and the back is kept vertical.

Walls should be made in rubble masonry consisting of hammer dressed hard stones. Masonry courses must be normal to face batter, and the back of the wall can be left rough. Masonry work should proceed in an uniform level.

In case of Dry rubble walls, it is generally advisable to bed each course in stone dust or earth to spread the load and increase the frictional resistance between courses.

Backfill: The backfill layer immediately behind the wall should consist of hand packed stone or some granular material. Remainder backfill should be rammed in

150 mm thick layers sloping towards the back of the wall. The top surface should better be sealed with bituminous macadam to prevent unnecessary direct seepage of water in the retaining wall increasing thereby back pressure.

Drainage: Provision must be made to prevent water accumulating behind wall. Adequate staggered weep holes not less than 15 cm x 10 cm should be provided at one metre interval both horizontally and vertically.

When provided, weep holes should have a minimum diameter of about 0.1 m and be adequately spaced. Note that there is always a possibility that backfill material may be washed into weep holes or drainage pipes and ultimately clog them. Thus, filter material needs to be placed behind the weep holes or around the drainage pipes, as the case may be geotextiles now serve that purpose.

Two main factors influence the choice of filter material: The grain-size distribution of the materials should be such that (a) the soil to be protected is not washed into the filter and (b) excessive hydrostatic pressure head is not created in the soil with a lower hydraulic conductivity. The preceding conditions can be satisfied if the following requirements are met.

DRAINAGE IN RURAL ROADS

9. DRAINAGE IN RURAL ROADS

9.1. Introduction:

The main objective of drainage is to prevent damage of the pavement due to entry of excess water and to prevent saturation up to a depth of 1meter below the top of the subgrade.This can be achieved by proper design of pavement which includes effective drainage system. An adequate drainage system includes the control of rain or surface flow and also the underground seepage or water held by capillary action (Soil suction)

VARIOUS TYPES OF DAMAGES ARISING DUE TO INADEQUATE DRAINAGE

1. Pavement failures like potholes, rutting, waviness and corrugation in flexible pavement.
2. Reduction in strength of many pavement materials, like, stabilised soil and water bound macadam due to increase of moisture content.
3. Damages to shoulder and pavement edges from surface water.
4. Considerable erosion of the soil from the substrata, slopes of embankment, cut and hillside due to surface water.

Therefore, an adequate drainage is required for maintaining the structural and functional adequacy of the road. In India, unfortunately not as much attention is being paid to drainage, as it deserves, with obvious dangerous consequences. It has been conclusively established that if drainage of the pavement is improved, the cost of the maintenance/repair goes down considerably. It is estimated that cost of drainage measures works out to 3 to 5 per cent of the total cost of the construction. This small investment for drainage provisions at the initial stage pays rich dividend in the service period. Providing drainage measure at latter stage is both difficult and expensive, and therefore, proper provisions for adequate drainage should be made at the initial construction stage itself.

9.2. TYPES OF ROAD DRAINAGE

The road drainage woks may be broadly classified as under:

(i) Interception and drainage of surface water (Surface Drainage)

(ii) Interception and rapid removal of seepage or subsurface water (Sub-Surface Drainage)

These guidelines deal with drainage of rural roads running through plain, rolling and hilly terrains. The aspects covered are influence of alignment and geometrics of the road, surface drainage, sub-surface drainage and internal drainage of pavement structures. For rainfall less than 500 mm per annum, no internal drainage of pavement is required. It may be noted that some aspects of hill road drainage are also covered for the details of which relevant IRC specifications/guidelines may be referred.

9.3. GENERAL CRITERIA FOR ROAD DRAINAGE

Alignment of Road: The alignment of road has vital influence on the problem of drainage. The ideal alignment should avoid steep and heavy cut/fill, as these locations are vulnerable to drainage problems.

Embankment Height: The road subgrade level in fill section is to be fixed so that the difference between formation level and highest water table/high flood level is not less than 0.6 meter, and between formation level and ground level not less than 1.0 meter.

9.4. SYSTEMS OF DRAINAGE

In general the road drainage is catered by both surface and sub-surface drainage systems, for which a survey and field investigation should be carried out. It may include:

(i) Preparation of alignment plan, longitudinal section, contour map

(ii) Hydrological data, such as, rainfall and estimation of runoff

(iii) Hydrographical survey

(iv) Geotechnical investigation

9.5. SURFACE DRAINAGE SYSTEM

The fast disposal of runoff on the road surface is achieved by surface drains or roadside drains or catch water drains.

The problem of surface drainage is first tackled at the location survey stage. An ideal location for a highway from drainage point of view is along the divides between large drainage areas i.e. along the ridgeline. All the streams would then flow away from the highway and the drainage problem would be reduced to tackling the water that falls within the roadway boundary only. Except in hilly areas where easy gradients are available along the main streams, location of a highway along the streams involves construction of a large no of drainage structures at immense cost, which, if possible, should be carefully avoided. Construction of high embankments involves erosion problems, which require careful handling. This fact may also be taken into account while locating a highway. Drainage is, thus, one of the essential considerations for the location of a highway.

9.6.GEOMETRIC DESIGN OF ROAD

Providing camber on one side or both sides, proper slope to the shoulder and providing requisite longitudinal gradients, etc. disposes water from road surface.

9.7. LONGITUDINAL GRADIENT

The longitudinal gradient serves the natural means for drainage of rainwater collected over the road surface. Internal drainage through granular layers needs, a longitudinal gradient of 0.3 per cent for its effectiveness.

9.8. PAVEMENTS CROSS SLOPE/CAMBER

If a road is to perform adequately, care must be taken to remove the surface runoff by suitable cross falls, which will be helpful in minimizing ponding of the water. Therefore, higher than minimum cross fall/camber should be adopted where possible by the following means:

Cross fall or camber may be made to slope on one side in case of hilly areas to drain the surface water on the carriageway towards the hillsides where the gutters on both sides are not feasible.

When the road is on a gradient, it is desirable that the camber should not be less than 50 per cent of the longitudinal gradient subject to minimum of specified camber. This is essential to ensure the surface water to reach the shoulders quickly.

Table 9.1 Cross Slope/Camber for Different Surface Types
(IRC SP : 20 - 2002, Page No. 111)

Surface Type	Camber (Per cent)	
	Annual Rainfall (more than 1000 mm)	Annual Rainfall (less than 1000 mm)
Earth	4.0	5.0
WBM & Gravel	3.5	4.0
Thin Bituminous Surface	3.0	3.5
Rigid Surface	2.0	2.5

9.9. SURFACE DRAINS

The water from road and adjacent area shall be collected and lead away to natural out falls. This is achieved by surface drains:

(i) Drain along the side of the road (gutter)

(ii) System of suitable drains, such as, shoulder drains (iii) Deep catch water surface drain on the hillside

9.10. ROADSIDE DRAINS

The function of roadside drain is to collect surface water from the roadway and lead it to an outlet. Another function of roadside ditches is to drain out the base course of the roadway structure so as to prevent its saturation and consequent loss in load bearing capacity as illustrated in Fig.9.2. In absence of properly designed roadside ditches, the surface water from the roadway, as well as water collected from cut slopes accumulates, causing serious damage by erosion to the roadway, as well as formation slopes.

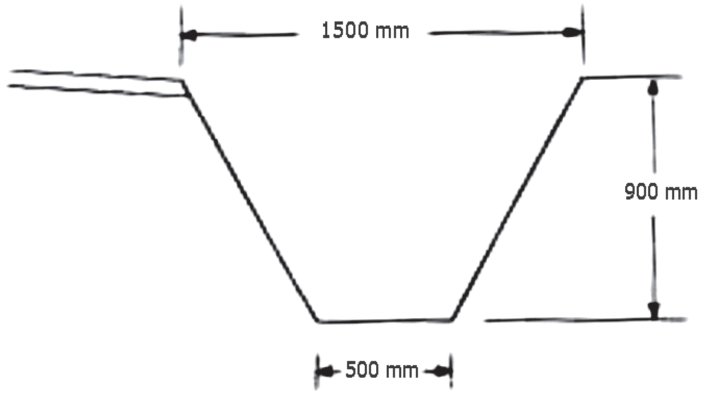


Fig: 9.1. a) Typical Cross Section of Side Drain in soil

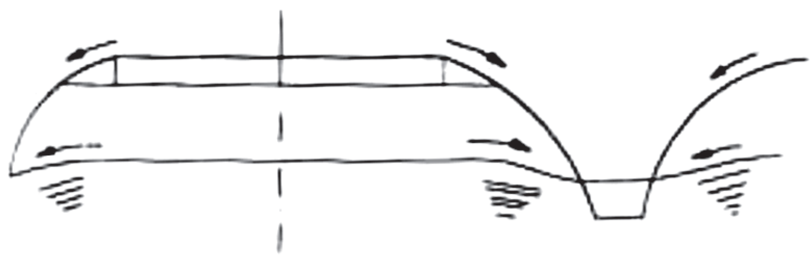
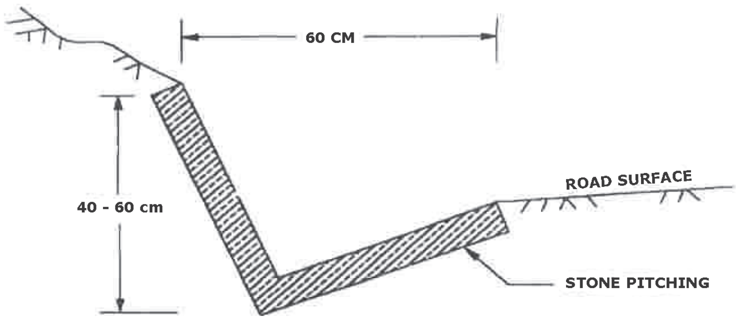


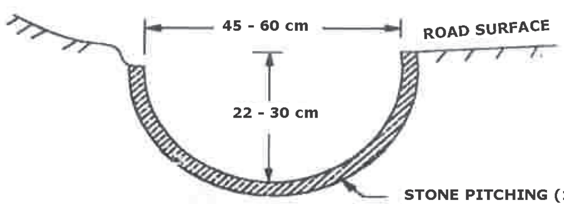
Fig: 9.2. b) Function of Safe Drain

The side drains are designed on the principles of open channel flow, and generally provided on both sides of the road. In case of hilly terrain, side drains on hillside are made when road is built in cut section. They should be provided below the subgrade of the road.

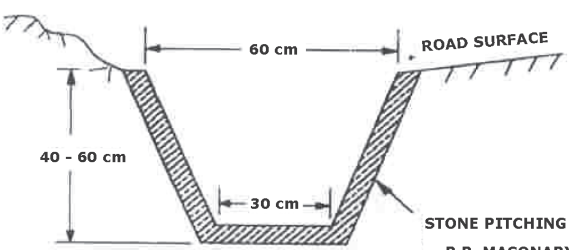
Roadside drains in hilly terrain are constructed to parabolic (saucer shape), trapezoidal, triangular, v-shape, kerb and channel or U-shaped cross-sections. The parabolic section is hydraulically the best and most erosion resistant. However, the trapezoidal section is easier to construct and is generally adopted. U-shaped drains are generally deep drains and are provided where higher discharge has to be catered and road width is available.



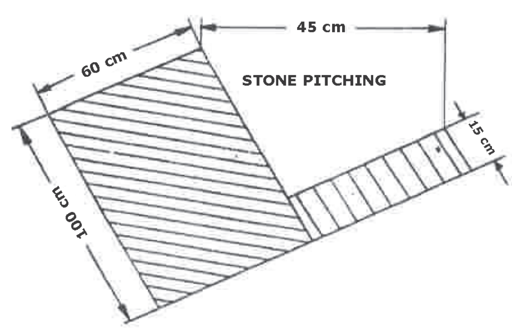
(a) V - SHAPED DRAIN



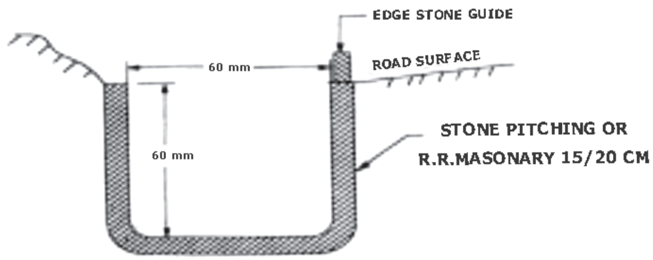
(a) PARABOLIC OR SAUCER TYPE DRAIN



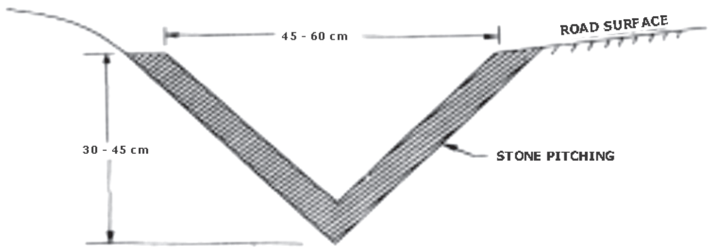
(c) TRAPEZOIDAL DRAIN



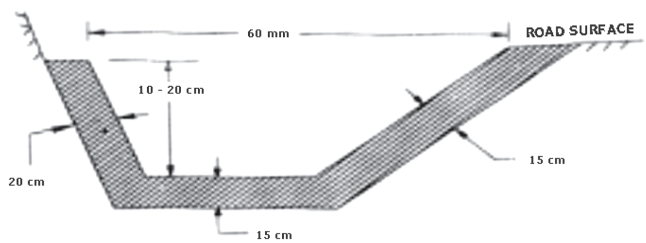
(d) TYPICAL SECTION OF TOE WALL AND DRAIN



(e) U - SHAPED DRAIN

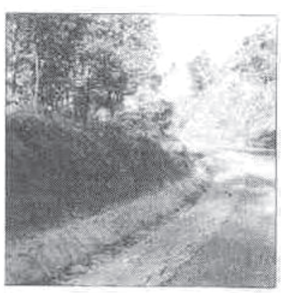


(f) TRIANGULAR DRAIN

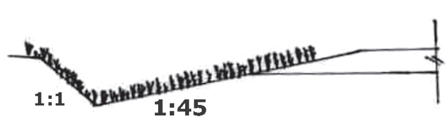


(g) KERB AND CHANNEL DRAIN

Trapezoidal Drain



Conventional Vee-Shapped Drain



The lining of side gutters is a costly proposition, and therefore, judicious selection of the type of lining is very essential. It is more cost effective and desirable to provide bigger size gutter (section) than any lining. Bigger section reduces damages to the pavement and also reduces the maintenance liabilities.

To estimate the runoff at a given location, the rational formula relating rainfall to runoff is used for catchment areas not exceeding 50 sq.km. The formula states that:

$$Q = 0.028\ PAI_C$$

Where

Q = Discharge (Peak runoff) in cum/sec

P = Coefficient of runoff for the catchment characteristics

A = Area of catchment in hectares from toposheet

I_C = Critical Intensity of rainfall in cm per hour for the selected frequency and for the duration equal to the time of concentration

The coefficient of runoff for different surfaces is provided in Table: 9.2.

Table: 9.2. Suggested Values of Coefficient of Run-Off (IRC SP : 20 - 2002, Page No. 115)

Sl. No.	Description of Surface	Coefficient of runoff (P)
1	Steep bare rock and watertight pavement surface (concrete or bitumen)	0.9
2	Steep rock with some vegetative cover	0.8
3	Plateau areas with light vegetative cover	0.7
4	Bare stiff clayey soils (Impervious soils)	0.6
5	Stiff clayey soils (impervious soils) with vegetative cover and uneven paved road surfaces	0.5
6	Loam lightly cultivated or covered and macadam or gravel roads	0.4
7	Loam largely cultivated or turfed	0.3
8	Sandy soils, light growth, parks, gardens, lawns and meadows	0.2
9	Sandy soil covered with heavy bush or wooded/ forested areas	0.1

The selection of roadside drain is based on magnitude and duration of flow. The hydrological data required for design of gutter are drainage area, water shed delineation, direction of flow, location of outfalls, ditches, other surface drainage facilities, ground surface condition, rainfall and flood frequencies. The roadside drains are designed on the principle of flow in open channel based on Manning's formula which states that:

$$Q=AV$$

where $V=(1/n)R^{2/3}S^{1/2}$

Q = Discharge in cum/sec

V = Mean Velocity in m/sec

N = Manning's Roughness coefficient

R = Hydraulic radius in m which is area of flow cross-section divided by wetted perimeter

S = Energy slope of the channel, which is roughly taken as slope of drain bed

A = Area of the flow cross-section in m^2

The value of Manning's coefficient and permissible velocity of flow to prevent erosion are given in Table: 9.3.

Table: 9.3.

Sl. No.	Ditch Lining	Manning's 'n'	Permissible Velocity m/sec
Natural Earth Drain			
A.	**Without Vegetation**		
	(i) Rock		
	(a) Smooth & Uniform	0.035-0.040	6.0
	(b) Jagged & Irregular	0.04-0.045	4.5-5.5
	(ii) Soils (Extended Casagrande classification)		
	GW	0.022-0.024	1.8-2.1
	GP	0.023-0.026	2.1-2.4
	GC	0.020-0.026	1.5-2.1
	GF	0.024-0.026	1.5-2.1
	SW	0.020-0.024	0.3-0.6
	SP	0.022-0.024	0.3-0.6
	SC	0.020-0.023	0.6-0.9
	SF	0.023-0.025	0.9-1.2
	CL & CT	0.022-0.024	0.6-0.9
	MI & ML	0.023-0.024	0.9-1.2
	OL & OI	0.022-0.024	0.6-0.9
	CH	0.022-0.023	0.6-0.9
	MH	0.023-0.024	0.9-1.5
	OH	0.022-0.024	0.6-0.9
	Pt	0.022-0.025	0.6-0.9
B.	**With Vegetation**		
	(i) Average turf		
	(a) Erosion resistant soil	0.050-0.070	1.2-1.5
	(b) Easily erode soil	0.030-0.050	0.9-1.2
	(ii) Dense turf		
	(a) Erosion resistant soil	0.070-0.090	1.0-2.4
	(b) Easily erode soil	0.040-0.050	1.5-1.8
	(c) Clean bottom with brush sides	0.050-0.080	1.2-1.5
	(d) Channel with tree stumps		
	No sprouts	0.040-0.050	1.5-2.1
	With sprouts	0.060-0.080	1.8-2.4
	(e) Dense weeds	0.080-0.012	1.5-1.8
	(f) Dense Brush	0.100-0.140	1.2-1.5
	(g) Dense willows	0.150-0.200	2.4-2.7

Paved Drain			
A.	**Concrete with all surfaces**		
	Good or Poor		
	(i) Trowel finished	0.012-0.014	6.0
	(ii) Float finished	0.013-0.015	6.0
	(iii) Formed, no finish	0.014-0.016	6.0
B.	**Concrete bottom, float finished with sides of**		
	(i) Dressed stone in mortar	0.015-0.017	5.4-6.0
	(ii) Random stone in mortar	0.017-0.020	5.1-5.7
	(iii) Dressed stone or smooth concrete rubble (Rip-rap)	0.020-0.025	4.5
	(iv) Rubble or random stone (Rip-rap)	0.025-0.030	4.5
C.	**Gravel bottom with sides of**		
	(i) Formed Concrete	0.017-0.020	3.0
	(ii) Random stone in mortar	0.020-0.024	2.4-3.0
	(iii) Rubble or random stone (Rip-rap)	0.023-0.033	2.4-3.0
D.	**Brick**	0.014-0.017	3.0
E.	**Bitumen (Asphalt)**	0.013-0.016	5.4-6.0

9.11. Procedure for design of side drain is generally in the following steps:

- Find discharge using rational equation
- Find area of cross-section using allowable velocity of side drain
- Find slope of side drain using Manning's formula
- Longitudinal slope should not be less than minimum slope of 0.5 per cent if side drains are lined and 1.0 percent if they are unlined as specified in IRC: 73-1980 "Geometric Design Standards for Rural Highways"

IRC: SP: 42 "Guidelines on Road Drainage" may be referred for detailed hydraulic design of the drain. However, the tentative salient design features of roadside drains (gutters) given below may be adopted in the absence of any data.

1. 300 mm deeper than the bottom of road crust
2. Minimum width at bottom - 450 mm
3. Minimum longitudinal - 0.5 percent
4. Discharge - 0.50 cum/sec
5. Shape - Triangular, Rectangular and Trapezoidal
6. Side slope generally not exceeding 1 in 4

The rectangular or trapezoidal section causes a sense of danger to the motorist travelling close to it, but triangular section is most appropriate and widely used.

An unlined drain can withstand only a limited amount of discharge without erosion problem. The problem will be severe in silt and sand when the velocity of flow is between 0.3 to 1.0 m/sec. In stiff clay this velocity may be 1.5 m/sec. But in all cases the permissible velocity of flow can be increased significantly by lining the drain. Also by lining the side slopes (of drain) can be made steep. An unlined cross-section of drain may-require 4:1 to 2:1 side slope, but a section with brick lining can be rectangular. Generally, in rural roads turfing is done in the roadside drains to prevent (soil) erosion of unlined drains. However, suitability can be improved by adopting different types of lining in side drains as given in Table: 9.4.

Table: 9.4. Suitability of Different Types of Lining in Side Drains

Types of lining	Brief Description	Suitable for	Unsuitable for
Turfing	Turfing is useful in humid area for preventing erosion	Triangular drain having 4:1 to 3:1 slopes	Rectangular, Trapezoidal drains since maintenance is difficult
Stone	Brick masonry stone/ bricks can be laid dry or bedded in concrete with joints fitted in cement mortar	(i) When drains are required to carry a large amount of debris (ii) Velocity is high	In known unstable area
Concreting	-do-	-do-	-do-
Stone slab lining		(i) Useful in triangular Section drains and in other section in combination with masonry/ concreting (ii) In areas where f l a t stone is easily available	
Boulder Pitching		Area with stable slopes	In unstable loose strata
Bituminous treatment	It is primary uick sealing of the surface. 10 to 15 cm impregnated with bitumen cutback or emulsion on the sides and base	Used in conjunction with boulder pitching in catch water drains for prevention of seepage flow	

9.12. SHOULDER DRAINAGE

Drainage from shoulder is ensured by properly maintaining the surface of the shoulder with specific camber. Shoulder should be shaped regularly before and during the monsoon, in order to avoid damages to the road pavement. A shoulder normally consists of granular material. However stabilised shoulders are preferred in case of clayey soil. Alternatively, following measures may be adopted when shoulders are of impervious material, like clay or black cotton soil, such as:

(i) Laying of continuous drainage layer of 75 mm to 100 mm thick under shoulder at the bottom level of sub-base as shown in Fig. 9.3.

(ii) Extending the sub-base/base course with drainage material in the entire formation width upto the edge of formation and provide a generous cross slope to permit rapid drainage as drawn in Fig. 9.4.

(iii) Provision of shoulder drains at 4 to 10 metres centre to centre as drawn in Fig. 9.5.

(iv) Shoulder with hard material, like granular or stabilised soil to effect good drainability.

The cross slope of the shoulder should be 1 per cent steeper than the cross slope of carriageway subject to minimum of 4 per cent. At times super elevation creates certain problems for the shoulder slopes on horizontal curve. In such stretches, shoulder on inner side of the curve should have a somewhat steeper slope than the pavement and shoulders on the outer side of the curve through shoulder drains. In case of earth shoulders with low permeability, i.e., black cotton soil, the drainage should be improved by providing shoulder drains. Shoulder drains provided at a spacing of 5 to 10 metre centre to centre as shown in Fig. 9.5 are preferred.

9.13. CATCH WATER DRAIN

These drains are provided on hill slopes to intercept water flowing from upper reaches and guide such flow towards culverts. Such drains should be provided in suitable hill slopes as shown in Figs. 9.6 to Figs. 9.8. The catch water drains may be simple gutters at suitable location at top of the slope and leading to natural watercourses. These drains of trapezoidal shape should be stone lined and cement pointed with a stone masonry wall to retain the slopes.

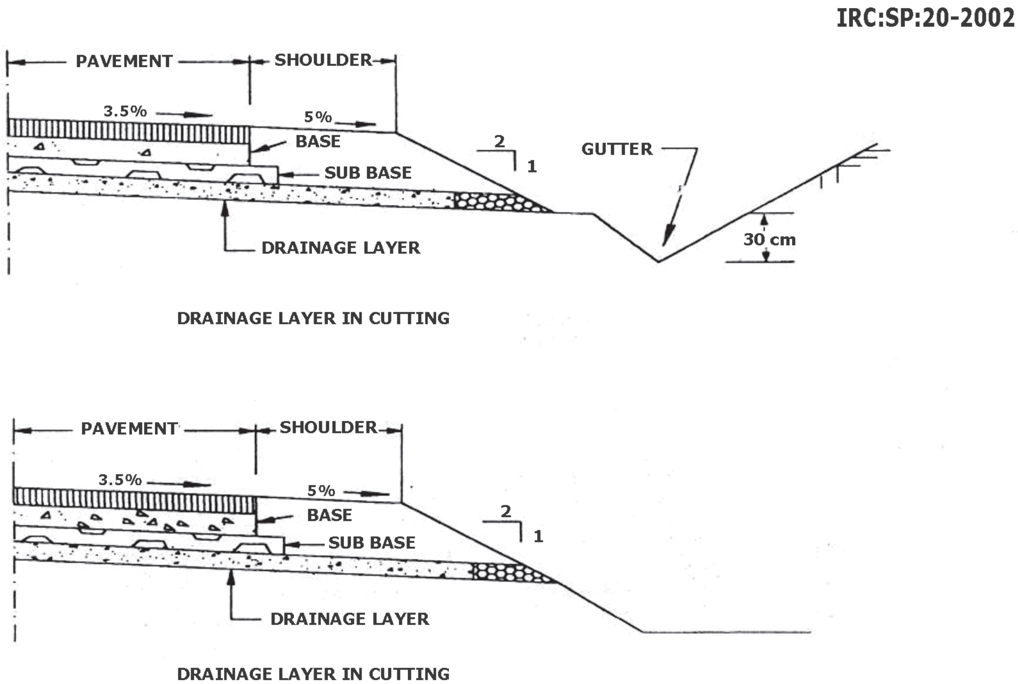


Fig: 9.3. Provision of Drainage Layer

9.14. SUB SURFACE DRAINAGE

Changes in moisture content of subgrade are caused by fluctuations in ground water table, seepage, percolation of rainwater and movement of capillary water and even water vapour. Hence it should be ensured that variation in moisture content in the subgrade is kept as minimum as possible. The type of subsurface drainage depends on the topography, depth and fluctuations in the ground water level and the type of subgrade.

Various measures that can be adopted at a specific situation are described below:

Continuous drainage layer should be laid over the entire formation width below the sub-base/base course as per gradation specified in Table: 9.5. In case of fine sand or silt or clayey subgrade or if annual rainfall is more than 1000 mm, a continuous layer of drainage material is required for the entire width of the formation as shown in Fig. 9.3.

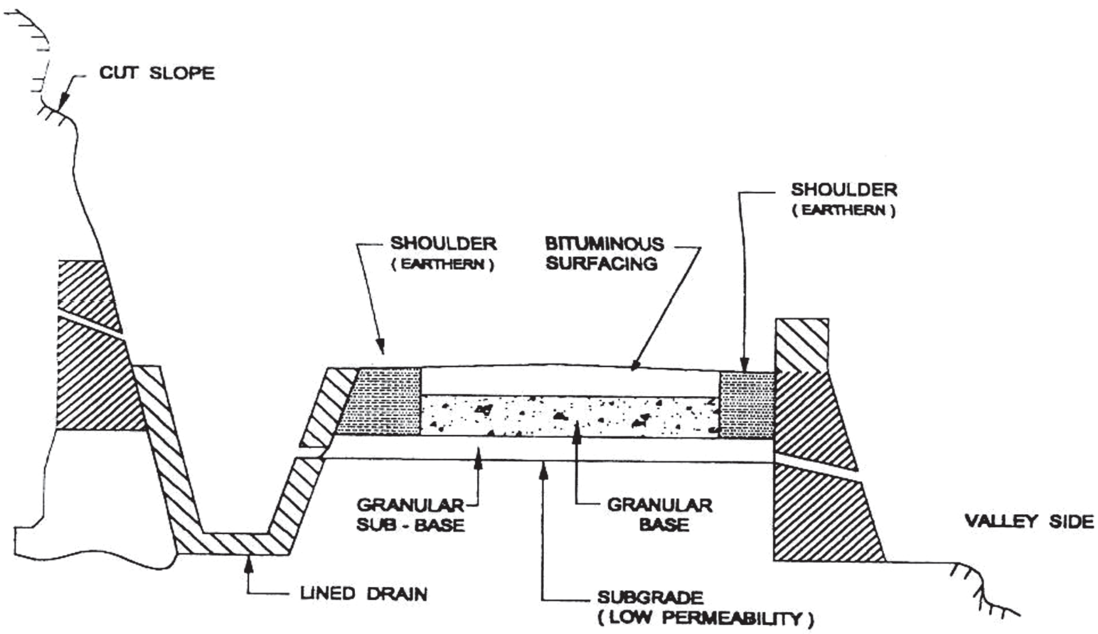
Table: 9.5. Gradation of Material for Drainage Layer
(IRC SP : 20 - 2002, Page No. 119)

IS Sieve Designation	Percent by Weight Passing the IS Sieve
75.0 mm	100
53.0mm	-
26.5mm	55-75
9.5mm	-
4.75mm	10-30
2.36mm	-
0.425mm	-
0.075mm	<5*

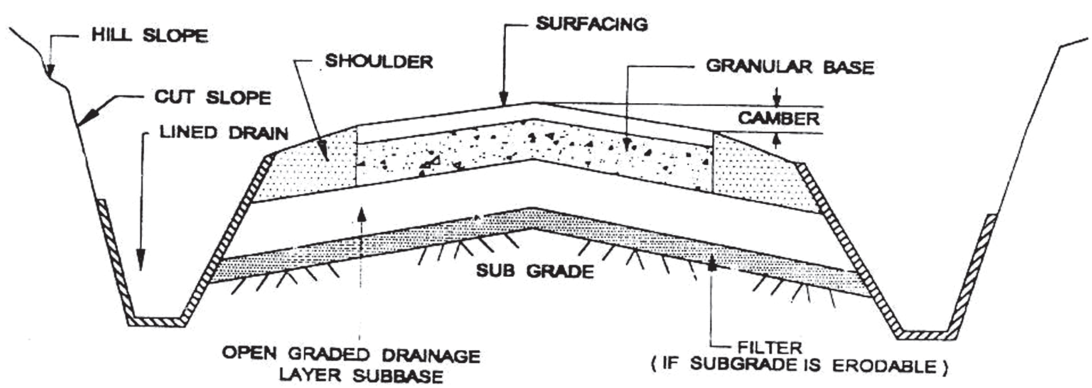
Note:

**In drainage layer, fine sand should not be used and the portion passing 75 micron should be restricted to 5 per cent. However, in exceptional situations the engineer should apply discretion and it should be restricted to a maximum of 10 per cent.*

IRC:SP:20-2002



(a) Road in Side Hill Cut



(b) Through Road in Hill Cut

Fig: 9.4. Drainage Through Opengraded Sub-base

IRC:SP:20-2002

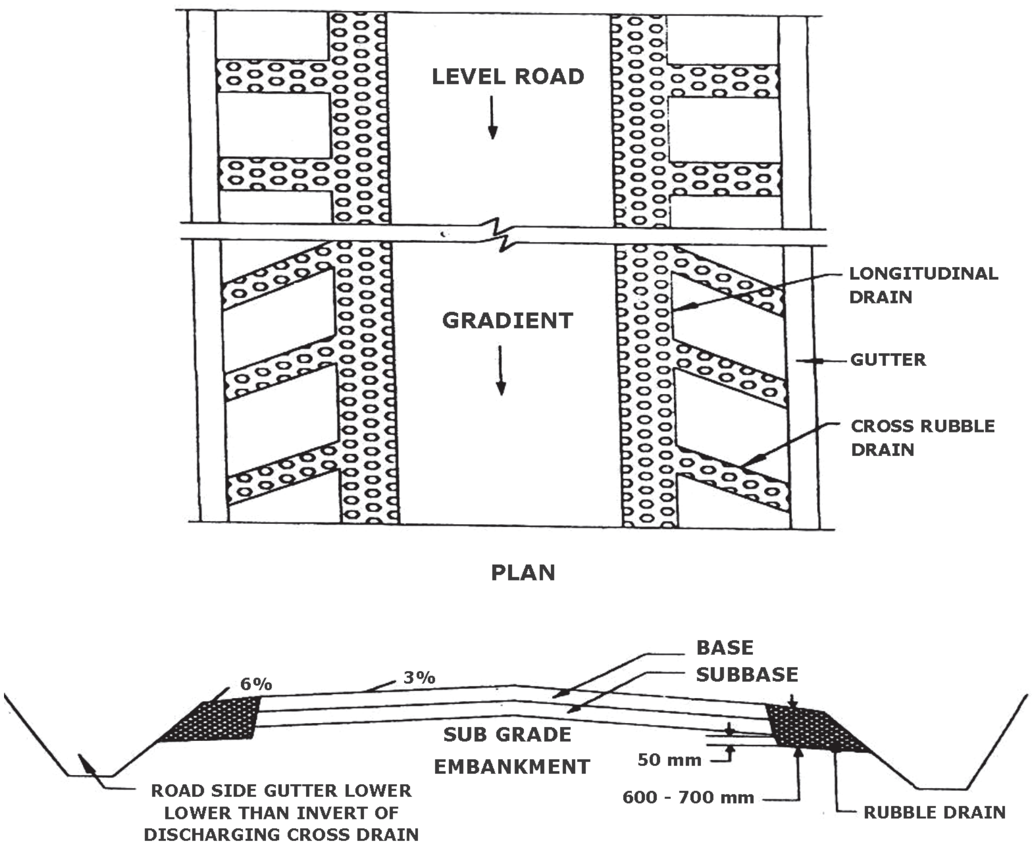


Fig. 6.6. Shoulder Drainage by Longitudinal and Diagonal Drains

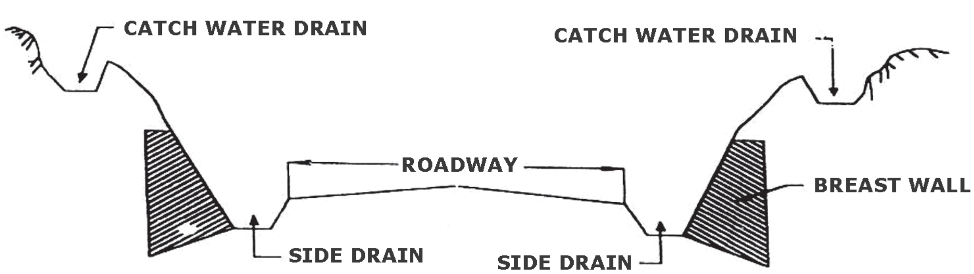


Fig. 9.6. Typical Box Cut

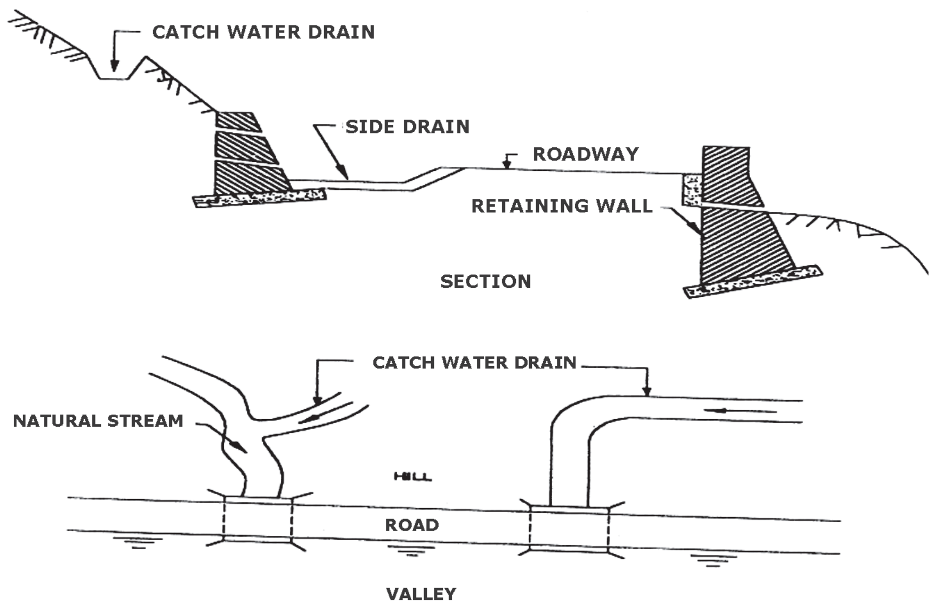


Fig. 9.7. Catch Water Drain in Stable Area

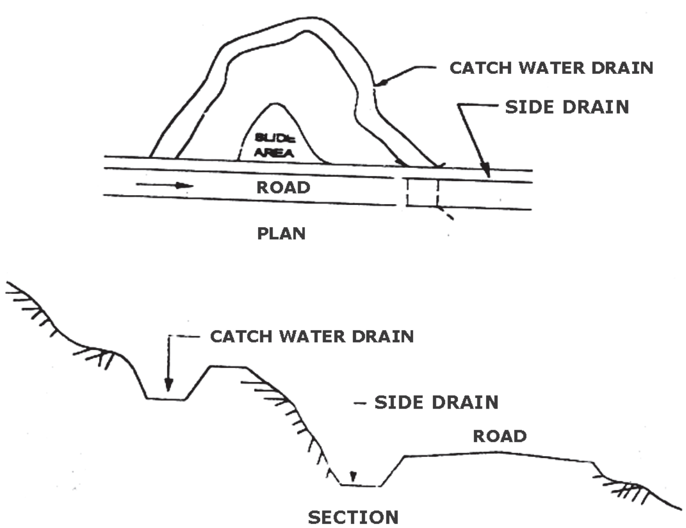
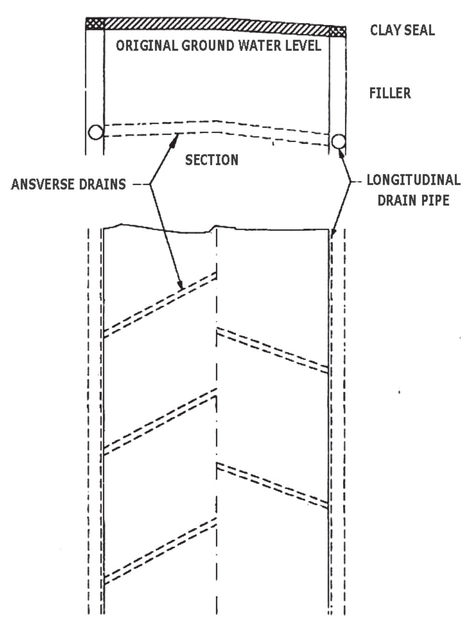


Fig. 9.8. Catch Water Drain in Slide Area

In rural roads with existing water bound macadam/gravel surfaces, drainage may be improved by providing aggregate drains in the shoulder as per Clause 309.3.7 of MoRT&H Specifications for road and bridge works.

It is recommended to lower the water table by providing subsurface drain (longitudinal) for relatively permeable soil subgrade as shown in Fig. 9.9. The subgrade drain may consist of perforated pipe or open jointed solid pipe in trench with backfill around it or it may be simply a free draining material in the trench without any pipe. The perforated pipes may be of metal, asbestos, cement etc. The top of trench is sealed by providing impervious cap so that only sub-surface water may enter the drain. In pipe drain, the internal diameter of pipe should not be less than 150 mm. Holes in perforated pipes may be formed in one half of the circumference only. Size of the holes may be close to D85 size of material surrounding the pipe subject to minimum of 3 mm and maximum of 6 mm. D85 denotes size of the sieve that allows 85 per cent of material to pass through it. The backfill may consist of sand-gravel material or crusted stone satisfying the grading of Table: 9.6. in case no specific design exercise based on filtration and permeability criteria has been carried out. The filter material (backfill material) should be free of organic material, clay balls and other deleterious material. The filter material is to be laid as per standard practice. The IRC: SP: 42 "Guidelines on Road Drainage" may be referred for detail design of the subsurface drains.



ig. 9.9. Sub-Surface Drainage System with Transverse Drains

Table 9.6. Grading Requirement For Filter Material
(IRC SP : 20 - 2002, Page No. 124)

Sieve Designation	Percent by Weight Passing the Sieve		
	Class I	Class II	Class III
53mm	-	-	100
45mm	-	-	97-100
26.5mm	-	100	-
22.4mm	-	95-100	50-100
11.2mm	100	48-100	20-60
5.6mm	92-100	28-54	4-32
2.8mm	83-100	20-35	0-10
1.4mm	59-96	-	1-5
710 μm	35-80	6-18	-
355 μm	14-40	2-9	-
180 μm	3-15	-	-
90 μm	0-5	0-4	0-3

Note:

1. *When the soil around the trench is fine grained (fine silt or clay or their mixture) adopt Class I grading. When coarse silt to medium sand or sandy soil exists then Class II grading is adopted. When gravelly sand is present then class III grading should be adopted.*
2. *The thickness of backfill material around the pipe should not be less than 150 mm. Therefore, considering that the minimum diameter of the pipe as 150 mm, the width of the trench should not be less than 450 mm.*

When the subsurface consists of only free draining material, the drain may be constructed without any pipe. The trench may be filled with material such as gravel, slag or stone aggregates free from organic and deleterious substances. This drain is known as aggregate drain. Its grading is indicated in Table: 9.7.

Table: 9.7. Gradation for Aggregate Drain (IRC SP : 20 - 2002, Page No. 124)

Sieve Designation, mm	Percent by Weight Passing
13.2	100
11.2	92-100
5.6	27-46
2.8	3-16
1.4	0-6

The sub-surface drain can be provided with geotextile either along the trench or around the pipe or both. The geotextile acts as both separation and filtration layer. When geotextile is provided, the filtration requirement in the grading is not important as far as material on both sides of it is concerned.

Intercepting a seepage zone as shown in fig: 9.10 can be done using horizontal drains. Perforated pipes are inserted in the hill cuts for removal of the moisture from the soil mass of up hill slope.

If some portions of road is required to be constructed in heavy clayey soils or passing through an area susceptible to ingress of water, subsoil drains as shown in fig. 9.11. may be provided in the road.

Sub soil drainage system has to be provided in valley curves. It consists of a trench cut across the body of the embankment/affected portion. The trench is filled with good drainage material such as gravel, sand, shingle, metal etc. A perforated pipe may also be provided in addition to the drainage material. The trapped moisture shall be drained to the trench bottom and discharged into side drain or outside the formation.

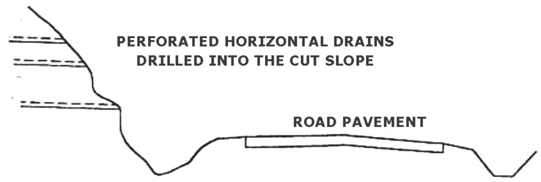


Fig. 9.10. Provision of Horizontal Drains

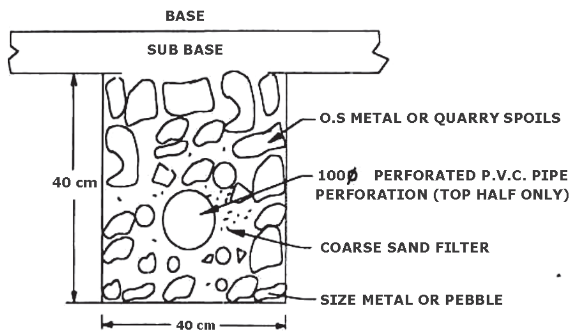


Fig. 9.11. Sub-Surface Drain in Heavy Clayey Soil

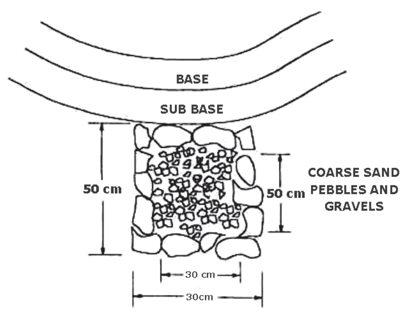


Fig. 9.12. Sub-Surface Drain at Valley Curve and Change of Grade

If the moisture reaching the subgrade due to capillary rise is likely to be detrimental, by providing a layer of granular material of suitable thickness of about 75 mm to 100 mm as cut-off layer during the construction of embankment between the subgrade and the highest level of ground water table or highest flood level.

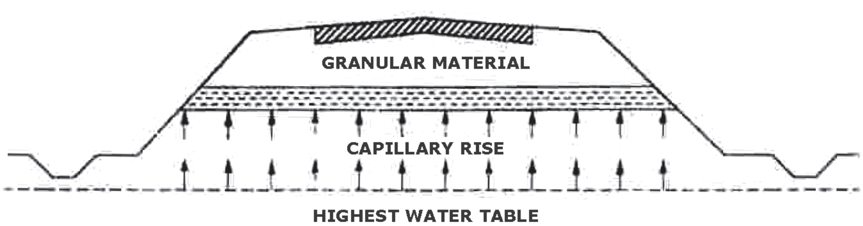


Fig. 9.13. Granular Capillary Cut-Off

QUALITY CONTROL

10. Quality Control

10.1. INTRODUCTION:

All materials before incorporation in the work shall be tested by the Contractor 'Prior to Construction'. The tests shall be carried out from each source. The test samples shall be representative of the material available from the source. Any change/ variation in the quality of material with depth of strata shall be reported. Important tests like the Moisture-Density relationship (Proctor Compaction), Aggregate Impact Value, Plasticity Index, CBR and any other tests specified by the Engineer shall invariably be carried out in the presence of the Engineer or his representative, who will not be below the rank of a Junior Engineer. The test results shall form the basis for approval of the source and the material for incorporation in the work and shall be approved by the Engineer. For manufactured items, however, such as concrete pipes, elastomeric bearings etc, a test certificate obtained by the Manufacturer from an approved Test House shall be accepted.

10.2. Quality Control Tests During Construction:

During execution of the work, quality control for workmanship and ensuring conformance to specifications shall be exercised on the basis of the tests indicated under 'Field Quality Control Tests During Construction'. The tests shall be carried out by the Contractor independently or in the presence of Employer's representative, normally a Junior Engineer, when available at site or where association of the Employer's representative in test is prescribed. The Junior Engineer shall record the results in his own handwriting. The Contractor shall be fully responsible for all the tests carried out for the work. The Assistant Engineer/AEE/Executive Engineer during their site visits shall have a few tests carried out in their presence and sign the Quality Control Register.

10.2.1. Stage Passing:

Supervisory officers of the level of AE, AEE and EE shall exercise quality control checks and certify the work of various stages on the basis of tests and their frequencies indicated under 'Quality Control Checks'. The officer certifying the work at various stages as prescribed shall be responsible for the quality and quantity of the work certified by him.

10.2.2. Procedure to form part of the Contract:

The prescribed tests, frequencies and the procedure for stage passing by Supervisory Officers shall be mandatory and shall form part of the Contract.

Flow Chart A typical flow chart for quality assurance checks during the construction of rural roads is given as an illustration in Figure: 10.1.

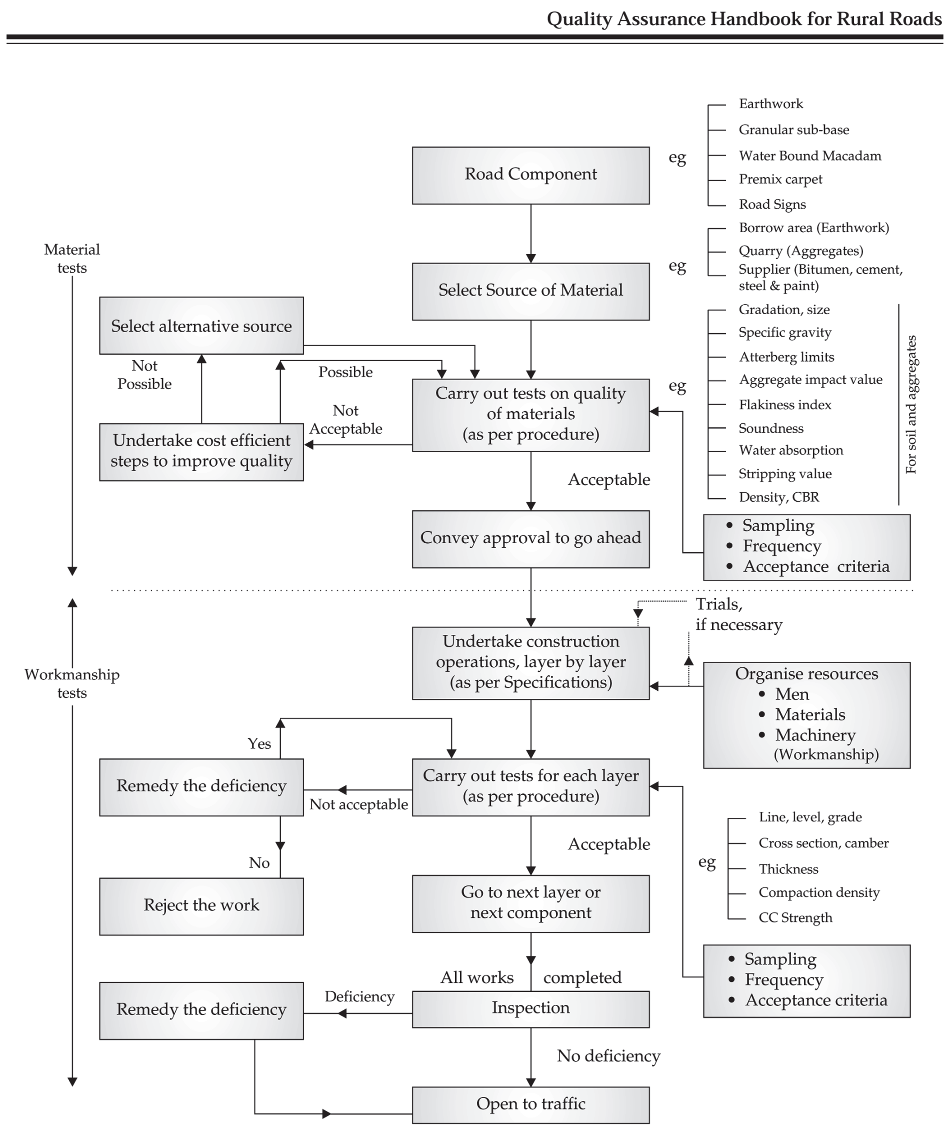


Fig: 10.1. Typical Flow Chart for Quality in Road Works

Notes:

1. *Field units shall maintain proper quality control records in the prescribed formats.*
2. *In addition to the quality control exercised by the PIU as described above, additional quality monitoring checks will be carried out by second and third tiers.*

10.2.3. Quality Control Field Laboratory

The Contractor shall be responsible to set up and maintain an adequately equipped Field Laboratory for routine tests for quality control required to be conducted on a day to day basis. The Field Laboratory will have normally those test equipment that do not require electric power supply and are relevant to the project specifications. Field Laboratory will be manned by suitably trained personnel in material testing and quality control works.

10.2.4. District Laboratory

The tests which are required to be done during the project preparation stage such as those pertaining to suitability of construction materials, selection of quarries etc. to be carried out before incorporation in the work as part of quality control or the tests which cannot be carried out in the Field Laboratory shall be conducted in the District Laboratory. The District Laboratory will cover the testing requirements for the entire District. Such a Laboratory shall be equipped with facilities for most of the tests, including those required for DPR preparation.

10.2.5. Quality Control of Works

10.2.5.1. Construction Equipment

1. For ensuring quality of work, an appropriate technology must be adopted. In the context of rural roads, an appropriate technology implies an optimum blend of manual methods and mechanical equipment of adequate capacity which may also involve use of agricultural implements towed by tractor.

2. Ensure that the equipment deployed is appropriate to the work and is properly operated and maintained.

3. Arrange a trial run of the equipment before commencement of the work.

4. Ensure that no equipment is deployed at or removed from the site of work without prior approval of the employer.

10.2.5.2. Setting Out :

Quality Control Requirements :

1. **Horizontal Alignment** Horizontal alignment shall be reckoned with respect to the centre line of the carriageway as shown on the drawings.

2. The permitted tolerances are given in Table: 10.1.

Table 10:1. Permitted Tolerances

Alignment	Plain and Rolling Terrain	Hilly Terrain
Edges of carriageway	± 20 mm	± 30 mm
Edges of roadway and / lower layers of pavement	± 30 mm	± 50

10.2.5.3. Methodology and Sequence of Work :

Ensure that a detailed construction methodology is submitted by the Contractor prior to start of the construction activities in accordance with the Contract Agreement. The construction methodology will include:

(i) Mechanical Equipment proposed to be used.

(ii) Sequence of various activities and schedule from start to end of the project.

10.2.5.4. Embankment Construction :

Quality Control Requirements of Materials :

(a.) The material used in embankment, sub-grade, shoulders, etc. shall be soil, moorum, gravel, a mixture of these or other material approved by the Engineer. It shall be free from logs, stumps, roots, rubbish, etc. The following types of material shall be considered unsuitable:

(i) Material from swamps, marshes and bogs

(ii) Peat, log, stump and perishable material; soil classified as OL, OI, OH or Pt as per IS:1498.

(iii) Materials susceptible to spontaneous combustion

(iv) Clay having liquid limit exceeding 70 and plasticity index exceeding 45

(v) Material with salts resulting in leaching action e.g. sodic soils (pH > 8.5)

(vi) Expansive clay with free swelling index exceeding 50 perent.

(vii) Materials in a frozen condition

(viii) Fill materials with a soluble sulphate content exceeding 1.9 gm of sulphate, (expressed as SO_3) per litre, if deposited within 500 mm or other distance described in the Contract, of concrete, cement bound materials or other cementitious materials forming part of permanent works.

(ix) Material with a total sulphate content (expressed as SO_3) exceeding 0.5 per cent by mass, if deposited within 500 mm or other distance described in the Contract, of metallic items forming part of permanent works

(b) The size of coarse material shall not ordinarily exceed 75 mm when placed in embankment and 50 mm when placed in sub-grade.

(c) Only the materials satisfying the density requirements given in Table: 10.2. should be used for the embankment.

Table: 10.2. Minimum Density Requirement for Suitability of Embankment/Sub-Grade Materials

SI.No	Type of Work	Max. laboratory dry
(a)	Embankment not subject to flooding - height upto 3 m - height more than 3 m	IS:2720, Part 7 Not less than 14.4 kN/ m^3 Not less than 15.2 kN/ m^3
(b)	Embankment subject to flooding	Not less than 15.2 kN/m^3

10.2.5.5. Horizontal Alignment

The alignment shall be reckoned with respect to the centre line of the carriageway as shown on the drawings. The edges of the roadway as constructed shall be within the following tolerances indicated in Table: 10.3.

Table: 10.3. Permitted Tolerances for Edges of Carriageway and Roadway

Description	Plain and Rolling Terrains	Hilly Terrain
Edges of carriage way	(±) 20mm	(±) 30mm
Edges of roadway and lower layers of pavement	(±) 30mm	(±) 50mm

10.2.5.6. Surface Levels

The permitted tolerance in surface level for sub-grade will be +20 mm and (-) 25 mm.

10.2.5.7. Surface Regularity

The maximum allowable difference between the road surface and underside of a 3 m straight edge shall be 20 mm for the longitudinal profile and 15 mm for the cross profile.

10.2.5.8. Degree of Compaction

The embankment shall be compacted to satisfy the density requirements given in Table: 10.4.

Table:10.4. Compaction Requirements for Embankment/ Sub-Grade/Expansive Clays

Type of work	Relative Compaction as percentage of maximum laboratory dry density
Embankment	Not less than 97 percent of Standard Proctor Density as per IS:2720 (Part 7)
Sub-grade (Top 300 mm of embankment and shoulders)	Not less than 100 percent of Standard Proctor Density as per IS:2720 (Part 7)
Expansive clays	
i) Sub-grade and 500 mm portion just below the sub-grade.	Not allowed
ii) Remaining portion of Embankment	Not less than 90 percent of Standard Proctor Density as per IS:2720 (Part 7)

10.2.6. Quality Control Tests and their Frequency

10.2.6.1. Tests Prior to Construction

The quality control tests to be carried out prior to construction and their frequency shall be as given in Table: 10.5.

Table: 10.5. Quality Control Tests and Their Frequency for Borrow Material, Earthwork for Embankment and for Subgrade

TYPES OF TEST	Frequency
A. Earthwork for Embankment	
1. Soil Classification as per IS:1498 i) Sieve Analysis (Wet Sieve Analysis except for cohesionless soils) ii) LL, PL and PI	One test from each source for one km or part thereof.
2. Standard Proctor Compaction Test (IS:2720 Part 7). Test results to ascertain Dry Density-Moisture Content Relationship.	-do-
3. Free Swell Index Test (IS:2720 Part 40) * (Test for free swell index to be conducted only in case of expensive soils)	-do-
4. Deleterious Content ** (i) Organic matter content by loss-on-Ignition method or as per IS 2720-Part 22. (ii) Total soluble sulphate content (IS 2720-Part 27) where suspected on past experience. This can be easily confirmed by a quick test using barium chloride.	-do- -do-

B. Earthwork for Subgrade (Cutting or Filling)	
(i) Tests at 1 to 4, under A above. (In case the soil for embankment meets the prescribed requirements for the Subgrade, the above four tests need not be repeated.)	One test for each km length or part thereof, from each source. ***
(ii) CBR Test (IS:2720 Part 16) soaked/unsoaked as specified.	One test for each km: this will comprise testing of 3 specimens and the CBR value will be reported as average of the three test values.

Notes:

**Test for free swell index to be conducted only in case of expansive soils*

*** Presence of deleterious content can be initially detected through colour, odour and existences of any organic matter. where such observations justify need for further testing, simple tests at (i) and (ii) above shall be carried out. Detailed testing as per IS:2720, part 22 and 27 shall be done only after presence of deleterious content is confirmed by simple tests.*

**** For hill roads, the frequency of tests may be increased depending upon the variability of the strata met.*

10.2.6.2. Tests During Construction The quality control tests to be carried out during construction and their frequency shall be as given in Table:10.6.

Table: 10.6. Field Quality Control Tests During Construction

Sl. No	Test	Frequency
1.	Placement Moisture (IS:2720 Part 2) Any of the rapid test methods for determination of moisture content can beused:	At least 3 tests daily (well spread over the day's work)
2.	Insitu Density Measurements (IS:2720 Part 28) (Each layer)	-do- (i) Average of 3 tests results shall not be less than the specified degree of compaction.

		(ii) Individual test values of the degree of compaction obtained shall not be less than 1% of the specified value of degree of compaction. (For example, for the specified 100% Proctordensity, the individual test value shall not be less than 99% of Proctor density and the average of the three (or more) tests carried out in a day shall not be less than 100% Proctor density).
3.	Thickness of subgrade layer.	At random

Table : 10.7. Quality Control Checks by Inspecting Officials

Stage	Test	Frequency
A. Top of the Embankment (Before placing Subgrade Layer)	(i) Degree of Compaction (IS:2720 Part 28)	Minimum 3 tests for each km length or part thereof, allowable tolerance in test values as per para 6.2. One of the tests shall be carried out at a depth of 150 mm form the top.
	(ii) Surface Regularity and Transverse Profile	Random Checking
B. Finished Sugrade	(i) Degree of Compaction (IS:2720 Part 28)	(a) One test for each 300 m lengh or part thereof. (b) One test for each 1000 m length or part thereof. One of the tests shall be carried out at a depth of 150 mm form the top.
	(ii) Surface Regularity and Transverse Profile / Camber/crossfall and superelevation	Random Checking

10.3. Earthwork in Cutting

Quality Control Requirements

10.3.1. Horizontal Alignment

The horizontal alignment should be reckoned with respect to the centre line of the carriageway as shown on the drawings. The edges of the roadway as constructed should be correct within a tolerance limit of (±) 30 mm in plain and rolling terrain and (±) 50 mm in hilly terrain.

10.3.2. Finishing

No point on the slopes shall vary from the designated slopes by more than 150 mm measured at right angles to the slope (300 mm in case of rock excavation).

10.3.3. Surface Levels

The tolerance in surface level for sub-grade will be (+) 20 mm and (-) 25 mm.

10.3.4. Surface Regularity

The maximum allowable difference between the sub-grade surface and underside of a 3 m straight edge shall be 20 mm for the longitudinal profile and 15 mm for the cross profile.

10.3.5. Quality Control Tests

Subgrade material shall be tested as per tests given in Table:10.5. If the material in the subgrade has a density of less than 100% of maximum dry density (IS:2720 Part 7), the same shall be loosened to a depth of 500 mm (depth could be reduced to 300 mm if insitu density is not less than 95% of maximum dry density) and compacted in layers to 100% of maximum dry density. The density of compaction shall be tested as per Table: 10.6. and checked as per Table 10.7.

10.4.Subgrade Construction

Quality Control Requirements

10.4.1. Materials

(i) The material used for subgrades shall be soil, moorum, gravel, a mixture of these or any other approved material. Material considered unsuitable for embankment construction shall not be used for sub-grade.

(ii) The material for subgrade shall be non-expansive in nature.

(iii) Where expansive clay with acceptable ? 'free swelling index' value is used as a fill material in embankment, the sub-grade and top 500 mm portion of the embankment just below the sub-grade shall be non-expansive in nature.

(iv) Any fill material which yields a maximum dry laboratory unit weight of less than 16.5 kN/m3 determined as per IS:2720 (Part 7) shall be considered unsuitable for use in subgrade.

(v) The size of coarse material in the soil shall ordinarily not exceed 50 mm when placed in the subgrade.

10.4.2. Surface Level

The permissible tolerances in surface levels of subgrade shall be (+) 20 mm and (-) 25 mm.

10.4.3. Surface Regularity

The maximum allowable difference between the subgrade and underside of a 3 m straight edge shall not exceed 20 mm for longitudinal profile and 15 mm for cross profile.

10.4.4. Quality Control Tests

The Quality Control Tests on Earthwork for Subgrade (in cutting or filling) and their frequency, prior to construction, shall be as per Table: 10.5.

The Field Quality Control tests during construction shall be as per Table: 10.6.

The Quality Checks shall be as per Table: 10.7.

10.5. ROCK CUTTING

10.5.1. Rock Excavation

Quality Control Requirements

1. All the materials, tools and equipment used for blasting operations shall be of approved type.

2. Excavation by blasting shall be to the lines indicated in drawings, with the least disturbance to the adjacent material.

3. The magazine shall have a lightning conductor.

4. The fuse to be used in wet locations shall be sufficiently water-resistant as to be unaffected when immersed in water for 30 minutes.

5. The rate of burning of the fuse shall be uniform and definitely known to permit such a length being cut as will permit sufficient time to the firer to reach a safe point before explosion takes place.

6. Detonators shall be capable of giving effective blasting of the explosives.

7. The blasting powder, explosives, detonators, fuses, etc. shall be fresh and not damaged due to dampness, moisture or any other cause.

8. The charge holes shall be drilled to required depths and at suitable places.

10.5.2. Presplitting Rock Excavation Slopes

Quality Control Requirements

1. Quality control requirements for rock cutting mentioned in Para IB above shall apply.

2. Drilling operations shall be controlled by the use of proper equipment and technique.

3. Only standard cartridge explosives prepared and packaged by explosive manufacturing firms shall be used in pre split holes.

4. The presplit face shall not deviate by more than 300 mm from the plane passing through adjacent holes.

5. When completed, the average plane of the slope shall conform to the slopes indicated on the drawings and at no point shall the completed slopes vary from the designated slopes by more than 300 mm as measured perpendicular to the plane of the slope.

6. In no case shall any portion of the slope encroach on the side drains.

10.6. FLYASH EMBANKMENT CONSTRUCTION

Quality Control Requirements

10.6.1. Material

(a) Flyash (Pond Ash):

Particle size analysis, Maximum Dry Density and Optimum Moisture Content as per IS:2720 (Part- 7), Graph of dry density plotted against moisture content for this test shall be submitted for approval of Engineer, before execution of work.

(b) Soil:

Soil for cover to the flyash embankment shall satisfy the requirements of a suitable material for embankment construction as per section 2.5.4.

(c) Sub-grade:

Sub-grade shall conform to the requirements of section 4.

5.2. Quality control tests and their frequency shall be as indicated in Table: 10.6 & 10.7.

10.7. Surface Drains

Quality Control Requirements of Materials

(a) Where the soil is erodable, line the drain with random rubble masonry with 1:5 cement- sand mortar.

(b) The turf and variety of grass used for erosion control must meet the specified requirements for use in the area.

(c) The materials used for other types of linings like brick masonry, stone masonry etc. must meet the relevant specifications given in Sections 600 & 700 of Quality Assurance Handbook for Rural Roads respectively. The cross-section and side slopes should conform to the specified Dimensions.

10.8. GRANULAR SUB-BASE

Quality Control Requirements

10.8.1. Materials

(i) **Grading:** The grading for granular sub-base (GSB) should conform to the requirements given in Chapter 4

(ii) **Atterberg limits:** the material passing 425 micron sieve when tested according to IS: 2720 (part 5) shall have liquid limit and plasticity index not more than 25 and 6 percent respectively. (iii) On clayey subgrades, the material passing IS Sieve 0.075 mm should not exceed 5 percent. (iv) CBR value: The material with a minimum CBR value of 20 will be acceptable for granular sub-base. In case the subbase material of the requisite CBR is not available within economical leads, the subbase material meeting any of the specified grading and other requirements with a soaked CBR of not less than 15 can be permitted with the approval of the competent authority. (v) The wet aggregate Impact Value (IS:5640) shall not exceed 50.

10.8.2. Horizontal Alignment

The edges of the sub-base shall be correct within a tolerance limit of (±) 30 mm in plain and rolling terrain and (±) 50 mm for hilly terrain.

10.8.3. Surface Levels

The tolerance in surface level for granular sub-base will be restricted to (+) 10 mm and (-) 20 mm. A grid of 10 m by 2.5 m may be formed to check the surface level. The cross profile should conform to the required camber.

10.8.4. Surface Regularity

The maximum permitted difference between the sub-base and 3 m straight edge shall be 12 mm for longitudinal profile and 10 mm for cross profile. The cross profile should conform to the required camber.

10.8.5. Degree of Compaction

Density shall be 100 per cent of maximum dry density for the material determined as per IS:2720, Part 7.

10.8.6. Quality Control Tests

10.8.6.1. Tests Prior to Construction

(i) The quality control tests to be carried out prior to construction are indicated in Table: 10.8.

(ii) For existing approved sources, the test frequency shall be as indicated in Table: 10.9.

(iii) For new sources, test frequencies shall be increased to atleast three tests for each source (average of three tests).

(iv) The samples shall be taken at representative locations and at mean depth of proposed excavation.

TABLE : 10.8. Quality Control Tests Prior to Construction

Sl.No	Type of Test	Frequency
1.	Soil Classification as per IS:1498. i) Wet Sieve Analysis, except for cohesionless soils ii) Liquid and Plastic Limits	Average of three tests from each source.
2.	Combined Grading and Plasticity tests on materials from different sources, mixed in the design proportions. This shall be done when materials from more than one source are combined.	One test on the combined material for 500 m length of road or part thereof.
3.	Proctor Compaction Test (IS:2720 Part 7).	One test on the material from each source or on the combined material, as the case may be.
4.	Wet Aggregate Impact Value Test (IS:5640) where soft/marginal aggregates are used e.g, Laterite, Kankar, Brick Ballast etc.	One test from each source identified by the Contractor.
5.	CBR test (IS:2720 Part 16) on representative sample compacted at 100% Proctor dry density.	One test per km length. (average of a set of three specimens).

Note: Where materials from more than one source are to be combined in the desired proportions, the tests at Sl. Nos. 2, 3 and 5 should be carried out on the combined material.

10.8.6.2. Tests During Construction :

The field quality control tests during construction are indicated in Table: 10.9.

TABLE : 10.9. Quality Control Tests during Construction

Sl.No	Type of Test	Frequency
1.	Wet Sieve Analysis (IS:2720 Part 4) on the GSB material combined in the design proportions from various sources.	Atleast one test to be carried out daily.
2.	Liquid and Plastic Limit tests (IS:2720 Part 5).	-do-
3.	Placement Moisture Content: Any of the rapid methods for determination of moisture content can be used. (IS:2720 Part 2)	Atleast 3 tests to be carried out daily, well spread over the day's work.
4.	Insitu Density measurements (IS:2720 Part 28).	-do-
5.	Thickness of Compacted layer	At random

Table: 10.10. Quality Control Checks by inspecting officials

Stage	Test	Frequency
1. Top of the First Layer before placing the next GSB layer	(i) Degree of Compaction (IS:2720 Part 28)	(i) Minimum 3 tests for 2 km length or part thereof, (ii) Individual test values of the degree of compaction attained shall not be less than 1% of the specified degree of compaction. For example, for the required degree of compaction of 100% Proctor Density, the individual test values shall not be less than 99% of Proctor Density and the average of three (or more) tests carried out in a day shall not be less than 100% Proctor Density).
	(ii) Surface Regularity and Transverse Profile	Random Checking
2. Finished GSB Layer	(i) Degree of Compaction (IS:2720 Part 28)	(a) Three tests per 2 km length or part thereof. (b) One test for each km length or part thereof
	(ii) Surface Regularity and Transverse Profile / Camber/crossfall and superelevation	Random Checking

10.9. GRAVEL/SOIL-AGGREGATE BASE AND SURFACE COURSE

Quality Control Requirements

10.9.1. Materials

(i) The grading for Gravel/Soil-Aggregate Base shall conform to the requirements given in Chapter 4 while the grading for Gravel/Soil-Aggregate Surface Course shall conform to the requirements given in Chapter 4. For the fraction passing 4.75 mm, wet sieve analysis should be done.

(ii) Wet Aggregate Impact Value (IS:5640) shall not exceed 40 and 30 when used in base and 30 when used in surfacing. (iii) Flakiness Index (IS:2386 Part I) shall not exceed 25 percent when used in base and 20 when used in surfacing. (iv) In high rainfall areas (annual rainfall of 1500 mm or above), coastal areas and where local soils are salt infested, if the water absorption value of the coarse aggregate is greater than 2 percent, the Soundness test shall be carried out on the material delivered to the site as per IS:2386 (Part 5).

(a) Loss with Sodium Sulphate, 5 cycles	:	12 per cent maximum
(b) Loss with Magnesium Sulphate, 5 cycles	:	18 per cent maximum

(v) If crushed slag is used, Clause 405.2.5 of MORD specifications shall apply.

(vi) If crushed gravel/shingle is used, not less than 90 per cent by weight of the gravel/shingle pieces retained on 4.75 mm sieve shall have at least two fractured faces.

(vii) The needed gradation shall be obtained by crushing, screening and blending processes as necessary.

(viii) Fine aggregate material passing 4.75 mm sieve shall consist of natural or crushed sand and fine mineral particles.

10.9.2. Horizontal Alignment

The edges of the Base shall be correct within a tolerance limit of (±) 30 mm in plain and rolling terrain and (±) 50 mm for hilly areas. The edges of the carriageway with Gravel/Soil-Aggregate Surfacing shall be correct within (±) 20 mm in plain and rolling terrain and (±) 30 mm in hilly terrain.

10.9.3. Surface Levels

The tolerance in surface level for Gravel/Soil-Aggregate Base and Surface will be restricted to (±) 10 mm. A grid of 10 m by 2.5 m may be formed to check the surface level.

10.9.4. Surface Regularity

The maximum permitted difference between the Gravel/Soil-Aggregate layer and 3 m straight edge shall be 12 mm for longitudinal profile and 10 mm for cross profile. The cross profile should conform to the prescribed camber.

10.9.5. Degree of Compaction

Density shall be 100 per cent of maximum dry density for the material determined as per IS:2720 Part 7.

10.9.6. Quality Control Tests

The quality control tests and their frequency for gravel/soil-aggregate base and surface construction shall be as per Tables 10.8,10.9 and 10.10.

10.10. LIME TREATED SOIL FOR IMPROVED SUBGRADE/ SUB-BASE

Quality Control Requirements

10.10.1. Materials

(i) **Soil:** For the lime treatment to be effective in bringing about significant reduction in PI and increase in the CBR value, the PI of the soil to be treated should generally be higher than 10.

(ii) **Lime**: Lime for lime-soil stabilization work shall be commercial dry lime slaked at site or pre-slaked lime delivered to the site in suitable packing. The lime shall have purity of not less than 70% by weight of CaO when tested in accordance with IS:1514

(iii) **Water**: The water to be used for lime stabilization shall be clean and free from injurious substances. Potable water shall be preferred.

10.10.2. Horizontal Alignment

The edges of the sub-base shall be correct within a tolerance limit of (±) 30 mm in plain and rolling terrain and (±) 50 mm in hilly terrain.

10.10.3. Surface Levels

The tolerance in surface levels for lime-treated improved subgrade shall be (+) 20 mm and (-) 25 mm; while for the lime-treated soil subbase shall be (+) 10 mm and (-) 20 mm. A grid of 10 m by 2.5 m may be formed to check the surface level.

10.10.4. Surface Regularity

The maximum permitted difference between the sub-base and 3 m straight edge shall be 12 mm for longitudinal profile and 10 mm for cross profile. In case of improved subgrade, the maximum permitted difference shall be 20 mm for longitudinal profile and 15 mm for cross profile. The transverse profile shall conform to the prescribed camber.

10.10.5. Degree of Compaction

When lime is used for improving the subgrade, the soil-lime mix shall be tested for CBR value. When lime stabilized soil is used in a sub-base it shall be tested for CBR value/ unconfined compressive strength (UCS). The laboratory CBR/ UCS value shall be atleast 1.5 times the minimum field value of CBR/ UCS stipulated in the Contract.

10.10.6. Quality Control Tests

10.10.6.1. Tests Prior to Construction

The quality control tests to be carried out prior to construction are indicated in Table 10.11.

Table :10.11. Quality Control Tests Prior to Construction

Sl. No	Type of Test	Frequency
1.	Purity of Lime (IS:1514)	One test for each lot of lime
2.	Determination of optimum quantity of lime to attain the specified reduction in PI and/or to achieve the specified CBR	Mean of two tests.
3.	Plasticity Index test (IS:2720 Part 5) of the lime-treated soil (mixed with the required amount of lime)	Mean of two tests per km length on the representative sample of a lime-treated soil mix with the required amount of lime.
4.	CBR (IS:2720 Part 16) or Unconfined Compressive Strength (IS:4332 Part 5) if specified.	One test on a set of 3 specimens per km length.

10.10.6.2. Tests during construction

Table: 10.12. Quality Control Tests during Construction

Sl.No	Type of Test	Frequency
1.	Pulverization of soil clods	Atleast 3 tests daily, well spread over the day's work.
2.	Placement Moisture Content (IS:2720 Part 2)	-do-
3.	Insitu Density measurements (IS:2720 Part 28)`	-do- (i) Average of 3 test results shall not be less than the specified degree of compaction. (ii) Individual test values of the degree of compaction attained shall not be less than 1% of the specified degree of compaction.
4.	Thickness of Compacted layer.	At random

10.10.6.3. Quality Control Checks

Table: 10.13. The quality control checks by Inspecting Officers

Stage	Test	Frequency
1. Compacted lime-treated layer	(i) Degree of Compaction (IS:2720 Part 28)	(a) Minimum 3 tests for each two km length or par thereof; allowable tolerance in test values as per Table 403.3 (b) Minimum 1 test per km length or part thereof
	(ii) Plasticity Index of the lime-treated mix from the layer.	Minimum 3 tests for each km length or part
	(iii) Unconfined Compressive Strength (IS:4332 Part 5) when specified, sample extracted from the compacted layer.	(a) One test for each 500 m length or part (b) One test for each km length or part thereof.
	(iv) Surface Regularity and Transverse Profile.	Random Checking

10.11. CEMENT TREATED SOIL SUBBASE AND BASE

Quality Control Requirements

10.11.1. Materials

(i) Materials to be stabilized: The material for cement treatment includes sand, gravel, laterite kankar, brick aggregate, crushed rock, slag or flyash or combination of these. Material for subbase/base should conform to the grading given in Table: 10.14.

Table: 10.14. Grading Limits Of Materials For Stabilization With Cement

IS Sieve	Per cent by Weight Passing IS Sieve	
	Sub-base Finer Than	Base wihtin the Range
53.0 mm	100	100
37.5 mm	95	95-100
19.0 mm	45	45-100
9.5 mm	35	35-100
4.75 mm	25	25-100
600 micron	8	8-65
300 micron	5	5-40
75 micron	0	0-10

For use in base course, the Liquid limit and Plasticity Index shall not exceed 45% and 20% respectively.

(ii) Cement: Cement shall comply with the requirements of IS:269, 455 or 1489

(iii) Lime: (If needed for pretreatment) as per section 9.

(iv) Water: The water for cement stabilization shall be clean and free from injurious substances.

10.11.2. Horizontal Alignment

The edges of the cement stabilized soil layer should be correct within a tolerance limit of (±) 30 mm in plain and rolling terrains and (±)50 mm in hilly terrain.

10.11.3. Surface Levels

The tolerance in surface levels for cement treated soil sub-base will be restricted to (+) 10 mm and (−) 20 mm while for cement-treated soil base, it will be restricted to (±) 10 mm. A grid of 10 m x 2.5 m may be formed to check the surface levels.

10.11.4. Surface Regularity

The maximum permitted difference between the cement stabilized soil layer

and 3 m straight edge shall be 12 mm for longitudinal profile and 10 mm for cross profile.

10.11.5. Minimum Compressive Strength

For use in base and sub-base courses, minimum 7-day unconfined compressive strength of 2.76 MPa and 1.7 MPa respectively is required.

10.11.6. QUALITY CONTROL TESTS

10.11.6.1. Tests Prior to Construction

The quality control tests to be carried out prior to construction are indicated in Table: 10.15.

Table: 10.15.

Sl.No	Type of Test	Frequency
1.	Quality of cement and Purity of Lime (IS:1514) (if used for pre-treatment)	One test for each lot
2.	Unconfined Compressive Strength Test (IS:4332 Part 5)	One test on a set of 3 specimens per km length.

10.11.6.2. Tests During Construction

The quality control tests to be carried out during construction are indicated in Table: 10.16.

Table: 10.16.

Sl.No	Type of Test	Frequency
1.	Pulverization of soil clods	Atleast 3 tests daily, well spread over the day's work.
2.	Placement Moisture Content (IS:2720 Part 2)	-do-
3.	Insitu Density measurements (IS:2720 Part 28)`	-do- (i) Average of 3 test results shall not be less than the specified degree of compaction. (ii) Individual test values of the degree of compaction attained shall not be less than 1% of the specified degree of compaction.
4.	Thickness of Compacted layer.	At random

10.11.6.3. Quality Control Checks by Inspecting officers

The quality control checks by Inspecting officers are indicated in Table: 10.17.

Table: 10.17.

Stage	Test	Frequency
1. Top of the compacted cement-treated layer	(i) Degree of Compaction (IS:2720 Part 28)	(a) Minimum 3 tests for each two km length or par thereof; allowable tolerance in test values as per Table 403.3
	(ii) Unconfined Compressive Strength (IS:4332 Part 5) when specified, sample extracted from the compacted layer.	(a) One test for each 500 m length or part (b) One test for each km length or part thereof.
	(iv) Surface Regularity and Transverse Profile.	Random Checking

10.12. WATER BOUND MACADAM SUB-BASE/BASE/SURFACING

Quality Control Requirements

10.12.1. Materials

(i) Coarse Aggregate

(a) Physical requirements Physical requirements of coarse aggregate for water bound macadam for sub-base, base and surfacing should conform to the requirements given in Table: 10.18. If the water absorption of aggregate is greater than 2 per cent, Soundness test should be carried out.

Table: 10.18. Physical Requirements of Coarse Aggregates for WBM

Test	Sub-base	Base	Surfacing
Aggregate Impact value	Less than 50	Less than 40	Less than 30
Flakiness index	Less than 30	Less than 25	Less than 20
Soundness test -Loss with Sodium Sulphate -Loss with Magnesium Sulphate	 Less than 12% Less than 18%	 Less than 12% Less than 18%	 Less than 12% Less than 18%

Aggregates like brick bats, kankar, laterite etc. which get softened in presence of water shall be tested for Aggregate Impact Value under wet conditions in accordance with IS:5640.

(b) Grading : The coarse aggregates should conform to the grading specified in the Contract and meet the requirements given in Chapter 4.

(i) Screenings The use of screenings shall be omitted in the case of soft aggregates like brick metal, kankar, laterite etc.

(a) Physical Requirements Screenings should normally consist of same material as the coarse aggregate. However, where economic considerations so warrant, non-plastic material such as moorum or gravel with LL less than 20 and PI less than 6 may be used. Fraction passing 75 micron should not exceed 10 percent.

(b) Grading The screening shall conform to the grading specified in Chapter 4.

Approximate quantities of coarse aggregate and screenings required for 100 mm compacted thickness of WBM Grading 1, and 75 mm compacted thickness of WBM Grading 2 and 3 are given in Chapter 4.

iii) Binding Material

Application of binding material may not be necessary when the screenings used are of crushable type. Binding material if used as a filler material shall comprise of a suitable material approved by the Engineer having a Plasticity Index (PI) of value less than 6 for subbase/base course and 4 –10 for surfacing course as determined in accordance with IS:2720 (Part 5). The quantity of binding material will depend upon the type of screenings. For estimation of quantities, the following may be adopted: 75 Quantity for 75 mm compacted thickness WBM = 0.06 – 0.09 m3 / 10 m2. Quantity for 100 mm compacted thickness WBM = 0.08 – 0.10 m3 / 10 m2.

10.12.2. Horizontal Alignment

The edges of the WBM sub-base/ base will be correct within a tolerance limit of (±) 30 mm in plain and rolling terrain and (±) 50 mm in hilly terrain. The edge of carriageway with WBM surfacing shall be correct within a tolerance limit of (±) 20 mm in plain and rolling terrain and (±) 30 mm in hilly terrain.

10.13.3. Surface Level

The tolerance in surface levels of the WBM would be as under: (a) Sub-base course (+) 10 mm, (-) 20 mm (b) Base course (±) 15 mm (c) Surfacing Course (±) 10 mm (A grid of 10 m by 2.5 m may be formed to check the surface levels).

10.12.4. Surface Regularity

The maximum allowable difference between the road surface and 3 m straight edge shall be as per Table: 10.19.

Table: 10.19. Maximum Permitted Undulations Measured with 3 M Straight Edge

Type of Construction	Maximum permissible difference	
	Longitudinal Profile BasCross Profile	
WBM Grade 1	15 mm	12 mm
WBM Grade 2/Grade 3	12 mm	8 mm

10.12.5. Quality Control Tests

10.12.5.1. Tests Prior to Construction The quality control tests to be carried out prior to construction are indicated in Table: 10.20.

Table: 10.20. Quality Control Tests Prior to Construction

Sl.No	Type of Test	Frequency
1.	Aggregate Impact Value Test (IS:2386 Part 4)	One test from each identified source.
2.	Aggregate Water Absorption Test (IS:2386 Part 3)	-do-
3.	Soundness Test of Aggregates (where water absorption, as at 2 above, exceeds 2%) (IS:2386 Part 5).	-do-
4.	Grading, LL and PI of Crushable Screenings (IS:2720 Part 5) (where Screenings are to be used from the same source as the Stone Aggregates, this test is not needed).	-do-
5	LL and PI of the Binding Material, when used.	-do-

10.12.5.2 Tests During Construction

The quality control tests to be carried out during construction are indicated in Table: 10.21.

Table: 10.21. Quality Control Tests during Construction

Sl.No	Type of Test	Frequency
1.	Grading of Stone Aggregates and Screenings (IS:2386 Part 1)	Atleast 2 tests to be carried out for a day's work.
2.	Flakiness Index of Stone Aggregates (IS:2386 Part 1	-do-
3.	PI of Crushable Screenings/binding material (IS:2720 Part 5)	Atleast 2 tests to be carried out for a day's work.
4.	Aggregate impact value (IS:2386-Part 4)	At random one test per km
5.	Thickness of Compacted layer.	At random

10.12.5.3. Quality Control Checks by Inspecting Officers

The quality control checks to be carried out by the Inspecting Officers are indicated in Table: 10.22.

Table: 10.22. Quality Control Checks by Inspecting Officers

Sl.No	Type of Test	Frequency
1.Top of the Finished WBM Layer	(i) Volumetric analysis	(a) One test for each 200 m length of the layer. (b) One test for each 500 m length of the layer.
	(ii) Plasticity Index	One test for each 500 m length of the layer (mean of two tests)
	(iii) Surface Regularity and Transverse Profile	Random Checking

10.13. WET MIX MACADAM BASE

Quality Control requirements

10.13.1. Materials

(i) Physical Requirements Coarse aggregate shall be crushed stone. If crushed gravel is used, not less than 90% by weight of gravel / shingle pieces retained on 4.75 mm sieve shall have at least two fractured faces. The aggregate shall conform to the requirements of Table: 10.23.

Table: 10.23. Physical Requirements of Coarse Aggregate for Wet Mix Macadam for Base Courses

Test	Test Method	Requirements
1. Aggregate Impact Value	IS:2386 (Part 4) or IS: 5640	40 % (maximum)
2. Flakiness Index	IS :2386 (Part 1)	25 % (maximum)
If water absorption value of coarse aggregate is greater than 2 %, soundness test shall be carried out.		

ii) Grading Requirements

The aggregate shall conform to the grading requirements indicated in Chapter 4.

(iii) Optimum Moisture Content :

Optimum Moisture Content shall be determined in accordance with IS:2720 (Part 7)

10.13.2. Horizontal Alignment

The edges of WMM base will be correct within a tolerance limit of (±) 30 mm in plain and rolling terrain and (±) 50 mm in hilly terrain.

10.13.3. Surface Level

The tolerance in surface levels of the WMM would be (±) 10 mm: (A grid of 10 m by 2.5 m may be formed to check the surface levels).

10.13.4. Surface Regularity

The maximum permissible undulation measured with a 3 m straight edge, in the longitudinal profile shall be 10 mm and for cross profile the irregularity shall not exceed 8 mm.

10.13.5. Quality Control Tests

10.13.5.1. Tests Prior to Construction

The quality control tests to be carried out prior to construction are indicated in Table: 10.24.

Table: 10.24. Quality Control Tests Prior to Construction

Sl.No	Type of Test	Frequency
1.	Aggregate Impact Value Test (IS:2386 Part 4)	One to two tests on representative sample from each source identified by the Contractor, depending on ariability.
2.	Flakiness Index Test (IS:2386 Part 1)	-do-
3.	Water Absorption Test (IS:2386 Part 3)	-do-
4.	Soundness Test, if the water absorption exceeds 2%	-do-
5.	Grading Test (IS:2386 Part 1)	-do-
6.	Atterberg Limits of portion of aggregate passing 425 micron sieve (IS:2720 Part 5)	-do-
7.	Proctor Compaction Test (IS:2720 Part 7) (after replacing the aggregate fraction retained on 22.4 mm sieve with material of 4.75 mm to 22.4 mm size) alongwith Dry Density-Moisture Content Relationship	-do

10.13.5.2. Tests During Construction

The quality control tests to be carried out during construction are indicated in Table: 10.25.

Table: 10.25. Quality Control Tests during Construction

Sl.No	Type of Test	Frequency
1.	Grading Test (IS:2386 Part 1)	Atleast one test per day.
2.	Aggregate impact value (IS:2386-Part 4)	At random one test per km
3.	Placement Moisture Content (IS:2720 Part 2)	Atleast three tests per day.
4.	Density of Compacted Layer (IS:2720 Part 28)	-do-
5.	Thickness of Compacted Layer	At random

10.13.5.3. Quality Control Checks by Inspecting Officers

The quality checks by Inspecting Officers are indicated in Table: 10.26

Table: 10.26.

Sl.No	Type of Test	Frequency
1. Top of the Finished WMM Layer	(i) Density of the compacted layer (IS:2720 Part 28)	(a) One test for each 500 m length or part of there of for each layer (b) One test for each 1000 m length or part of there of for each layer
	(ii) Surface Regularity and Transverse Profile	Random Checking

10.14. Shoulder Construction

Quality Control Requirements

10.14.1. Materials

The shoulder material should be with a maximum laboratory dry unit weight at not less 16.5 kN/m3 (as per IS:2720 Part 7) and LL and PI not to exceed 25 and 6 respectively or granular material quarry waste conforming to the requirements of GSB.

10.14.2. Horizontal Alignment

The edges of the shoulders should be correct within a tolerance limit of (±) 30 mm in plain and rolling terrain and (±) 50 mm in hilly terrain.

10.14.3. Surface Levels

The tolerance in surface levels of the shoulders should be (±) 10 mm. A grid of 10 m x 2.5 m may be formed to check the surface level.

10.14.4. Surface Regularity

The maximum permitted difference between the shoulder and 3 m straight edge will be 12 mm for longitudinal profile and 10 mm for cross profile.

10.14.5. Quality Control Tests

The quality control tests and their frequency for earth/hard shoulders should be exercised in accordance with the requirement of Subgrade/Granular Sub-base.

10.15. BITUMINOUS CONSTRUCTION

Quality Control Requirements

10.15.1. Material

(i) Crusher stone dust for crack filling should be a fine-grained material, passing 4.75 mm sieve.

(ii) The bituminous mixture to be used for patching should be either a hot mix or cold mix in accordance with appropriate specifications.

(iii) The material for profile corrective course should meet relevant specifications.

(iv) The binder for prime coat and crack filling should be a Slow Setting bituminous

emulsion (SS-1 grade) as per IS:8887. For sub-zero temperatures, however, a Medium Curing (MC) Cutback conforming to IS:217 can be used.

2.The prepared surface should comply with the permitted tolerances in respect of horizontal alignment, surface levels and surface regularity specified for base course as given below :

Table: 10.27.

(i)	Horizontal Alignment	Edges of the pavement layer	(±) 30 mm in plain and rolling terrain	(±)50 mm in hilly terrain
(ii)	Surface levels	Granular Surface Bituminous Surface	(±) 15 mm (±) 10 mm	
(iii)	Surface Regularity Granular/ Bituminous Surface	Longitudinal Profile Transverse Profile	12 mm 8 mm	

10.15.2. PRIME COAT OVER GRANULAR BASE

Quality Control Requirements

1. The viscosity requirements for bitumen emulsion will depend upon the type of surface as given in Table:4.11
2. A priming grade bitumen emulsion (slow setting) conforming to IS:8887 should be used.
3. Quality Control Tests

10.15.2.1. Tests Prior to Construction

The quality control tests to be carried out prior to construction are indicated in Table: 10.28. These tests shall be carried out on the bitumen binders (Emulsion/ Cutback) brought on the site by the Contractor for use in the work.

Table: 10.28. Quality Control Tests Prior to Construction

Sl.No	Type of Test	Frequency
1.	Viscosity (using Saybolt Furol Viscometer) (IS:8887)	One test for each lot
2.	Residue on 600 micron sieve (IS:8887)	-do-
3.	Storage Stability Test (IS:8887)	-do-
4.	Flash Point Test, where bituminous cutback is to be used (IS:217)	-do-
5.	Viscosity Test (IS:217), where bituminous cutback is to be used	-do-

10.15.2.2. Tests During Construction

The quality control tests to be carried out during construction are indicated in Table: 10.29.

Table: 10.29. Quality Control Tests during Construction

Sl.No	Type of Test	Frequency
1.	Temperature of Binder, when cutback is to be used	Regularly
2.	Rate of Spread of Binder	At least two tests per day.
3.	Curing of Primer	Before any subsequent treatment.

10.15.2.3. Quality Control Checks

The Assistant Engineer / Junior Engineer shall carry out checks daily and record the result in his own handwriting.

10.15.3. TACK COAT

Quality Control Requirements

10.15.3.1. Materials (i) Binder for Tack Coat Rapid setting bituminous emulsion Grade RS-1 complying with IS:1887 as specified in Contract. For sites at sub-zero temperature: Cutback Bitumen (Medium Curing Grade) as per IS:217.

10.15.3.2. Quality Control Tests

The quality control tests and their frequencies would be same as for Prime Coat in Tables: 10.28 and 10.29.

10.16. Bituminous Macadam

Quality Control Requirements

10.16.1. Material

The Bituminous Macadam shall be composed of aggregate meeting the physical requirements indicated in Table: 10.30. and a paving bitumen of penetration grade complying with IS:73 or as specified in the Contract. The grading and binder requirements shall be in conformity with the requirements indicated in Chapter 4.

Table: 10.30. Physical Requirements for Aggregates for Bituminous Macadam

Property	Test	Specification
Particle Shape	Flakiness Index IS:2386 Part 1	Max. 25 per cent
Strength	Aggregate Impact Value IS:2386 Part 4	Max. 30 per cent
Durability	Soundness IS:2386 Part 5 Loss in Weight SodiumSulphate Magnesium Sulphate	Max. 12 per cent Max. 18 per cent
Water Absorption	Water Absorption IS:2386 Part 3	Max. 2 per cent
Stripping	Coating and Stripping of bitumen- aggregate mixtures IS:6241	Min. retained coating: 95 per cent.

In colder regions of India or where the percent passing 0.075 mm sieve is on the higher side of the range, appropriate bitumen contents may be upto 0.5 percent higher, subject to the approval of the Engineer.

10.16.2. Horizontal Alignment

The edges of the bituminous macadam base should be correct within a tolerance limit of (±) 30 mm in plain and rolling terrain and (±) 50 mm in hilly terrain

10.16.3. Surface Level

The tolerance in surface level of the bituminous macadam would be (±) 6 mm.

10.16.4. Surface Regularity

The maximum allowable difference between the road surface and a 3 m straight edge would be 12 mm for longitudinal profile and 8 mm for cross profile.

10.16.5. Quality Control Tests

10.16.5.1. Tests Prior to Construction

The quality control tests to be carried out prior to construction are indicated in Table: 10.31.

Table 10.31. Quality Control Tests Prior to Construction

Type of Test	Frequency
1. Quality of Binder (Straight-run Bitumen) (IS:73) (a) Penetration Test (b) R&B Softening Point Test (c) Ductility Test	 One test per lot -do- -do-
2. Quality of Binder (Modified Bitumen) (IS 15462) (a) Penetration Test (b) R&B Softening Point Test (c) Elastic Recovery Test (d) Separation Test	 -do- -do- -do- -do-
3. Aggregate Impact Value Test (IS:2386 Part 4)	One test on representative sample per km length from each source identified by the Contractor
4. Flakiness Index Test (IS:2386 Part 1)	Two tests per source
5. Bituminous Stripping of Aggregate Test (IS:6241)	One test per source
6. Water Absorption (IS:2386 Part 3)	-do-
7. Soundness Test, if water absorption of aggregate exceeds 2% (IS:2386 Part 5)	-do-

10.16.5.2. Tests During Construction

The quality control tests to be carried out during construction are indicated in Table: 10.32.

Table: 10.32. Quality Control Tests during Construction

Sl.No	Type of Test	Frequency
1.	Grading of Aggregate (IS:2386 Part 1)	Atleast one test per day.
2.	Binder Content	Atleast two tests per day.
3.	Density of Compacted Layer	Atleast one test per day.
4.	Temperature of Binder before mixing	Regularly
5.	*Temperature of mix during laying and compaction	Regularly
6.	Thickness of compacted layer	Regular, at close intervals
7.	Aggregate impact value (IS:2386-Part 4)	At random one test per km

*Temperature measurement will be done by using metallic contact thermometer with digital display

10.16.5.3. Quality Control Checks by Inspecting Officers

The quality checks by Inspecting Officers are indicated in Table: 10.33

Table: 10.33. Quality Control Checks by Inspecting Officers

Sl.No	Type of Test	Frequency
1. Finished Bituminous Macadam Base Layer	(i) Desity of the compacted layer (IS:2720 Part 28)	(a) One test for each 500 m length or part of thereof for each layer (b) One test for each 1000 m length
	(ii) Binder Content Part thereof	One test for each 500 m length or part thereof
	(ii) Surface Regularity and Transverse Profile	Random Checking

10.17. BUILT-UP SPRAY GROUT

Quality Control Requirements

10.17.1. Materials

(a) Coarse Aggregates and Key Aggregates

(i) **Physical requirements:**

Aggregates should satisfy various physical requirements given in Table: 10.30

(ii) **Grading:**

The coarse aggregates and key aggregate should conform to the grading given in Table: 10.34.

Table: 10.34. Grading for Coarse Aggregates and Key Aggregates for Built-up Spray Grout

IS sieve designation (mm)	Cumulative percent by weight of total aggregate	
	Coarse Aggregate	Key Aggregate
53.0	100	—
26.5	40 - 75	—
22.4	—	100
13.2	0 - 20	40 -75
5.6	—	0 -20
2.8	0-5	0-5

(b) Bitumen

The binder should be paving bitumen of penetration grade complying with IS:73 or an appropriate grade of emulsion complying with IS:8887, where permitted or specified in the contract.

10.17.2. Horizontal Alignment

The edges of the Built-up Spray Grout layer should be correct within a tolerance limit of (±) 30 mm in plain and rolling terrain and (±) 50 mm in hilly terrain.

10.17.3. Surface Level

The tolerance in surface level of the Built-up spray grout should be (±) 6 mm.

10.17.4. Surface Regularity

The maximum allowable difference between the road surface and a 3 m straight edge should be 12 mm for longitudinal profile and 8 mm for cross profile.

10.17.5. Quality Control Tests

10.17.5.1 Tests Prior to Construction

The quality control tests to be carried out prior to construction are indicated in Table: 10.35.

Table: 10.35. Quality Control Tests Prior to Construction

Sl.No	Type of Test	Frequency
1.	Quality of Binder (Straight-run Bitumen) (IS:73) (a) Penetration Test (b) R&B Softening Point Test (c) Ductility Test	 One test per lot -do- -do-
2.	Quality of Binder (Modified Bitumen) (IS:15462) (a) Penetration Test (b) R&B Softening Point Test (c) Elastic Recovery Test (d) Separation Test	 -do- -do- -do- -do-
3.	Aggregate Impact Value Test (IS:2386 Part 4)	One test on representative sample per km length from each source dentified by the Contractor
4.	Flakiness Index Test (IS:2386 Part 1)	-do-
5.	Bitumen Stripping of Aggregate Test (IS:6241)	-do-
6.	Water Absorption (IS:2386 Part 3)	-do-
7.	Soundness Test, if water absorption of aggregate exceeds 2% (IS:2386 Part 5)	-do-

10.17.5.2. Tests During Construction

The quality control tests to be carried out during construction are indicated in Table: 10.36.

Table: 10.36. Quality Control Tests during Construction

Sl.No	Type of Test	Frequency
1.	Rate of spread of binder	At least one test daily
2.	Rate of Spread of aggregates	-do-
3.	Aggregate Grading (IS:2386 Part 1)	-do-
4.	Temperature of binder during spraying	Regularly, at close intervals
5.	Thickness of compacted layer	At random

10.17.5.3. Quality Control Checks by Inspecting Officers

The quality checks to be exercised by Inspecting Officers are indicated in Table: 10.37.

Table: 10.37. Quality Control Checks by Inspecting Officers

Stage	Test	Frequency
Completed layer of Built-up Spray Grout/Modified Penetration Macadam	Surface Regularity and Transverse profile	Random Checking EE

10.18. MODIFIED PENETRATION MACADAM

Quality Control Requirements

10.18.1. Materials

Aggregates should satisfy the requirements given in Table: 10.30. Bitumen shall be of paving grade S-35 to S-90

10.18.2. Horizontal Alignment

The edges of the Modified Penetration Macadam layer should be correct within a tolerance limit of (±) 30 mm in plain and rolling terrains and (±) 50 mm in hilly terrain.

10.18.3. Surface Levels

The tolerance in surface level of the Modified Penetration Macadam should be (±) 6 mm.

10.18.4. Surface Regularity

The maximum allowable difference between the road surface and a 3 m straight edge would be 12 mm for longitudinal profile and 8 mm for cross profile.

10.18.5. Quality Control Tests

The quality control tests and their frequencies would be as per Table: 10.35 and 10.36.

10.19. SURFACE DRESSING

Quality Control Requirements

10.19. 1. Materials

(a) Stone Chippings

(i) Physical requirements:

Stone chippings should satisfy the requirements given in Table: 10.30. except that water absorption shall be 1% maximum.

(ii) Grading:

The stone chippings should conform to the Grading given in Chapter 4.

(b) Bitumen

The binder should be bituminous material, which may be as per the contract, or as decided by the Engineer.

- Paving grade bitumen (IS 73)
- Modified bitumen (IS 15462)
- Rapid setting bitumen emulsion (IS 8887)

(c) Where aggregate fails to pass the stripping test, an approved adhesion agent may be added to the binder, in accordance with the manufacturers instructions.

10.19.2. Horizontal Alignment

The edges of the Surface Dressing should be correct within a tolerance limit of (±) 20 mm in plain and rolling terrain and (±) 30 mm in hilly terrain.

10.19.3. Surface Level

The tolerance in surface level of the surface dressing would be (±) 6 mm for machine laid and (±) 10 mm for manually laid surface dressing.

10.19.4. Surface Regularity

The maximum allowable difference between the pavement course and a 3 m straight edge shall not exceed 10 mm for longitudinal profile and 12 mm for cross profile respectively.

10.19.5. Quality Control Tests

10.19.5.1 Tests Prior to Construction

The quality control tests to be carried out prior to construction are indicated in Table: 10.38.

Table: 10.38. Quality Control Tests Prior to Construction

Sl.No	Type of Test	Frequency
1.	Quality of Binder (Straight-run Bitumen) (IS:73) (a) Penetration Test (b) R&B Softening Point Test (c) Ductility Test	 One Set of tests per lot (Average of three tests) -do- -do-
2.	Quality of Binder (Bitumen Emulsion) (a) Viscosity (IS:8887) (b) Residue on 600 micron sieve (IS:8887) (c) Storage Stability Test (IS:8887)	 -do- -do- -do-
3.	Quality of Binder (Modified Bitumen) (IS:15462) (a) Penetration Test (b) R&B Softening Point Test (c) Elastic Recovery Test (d) Separation Test	 -do- -do- -do- -do-
4.	Aggregate Impact Value Test (IS:2386 Part 4)	One test per km length on representative sample from each source identified by the Contractor
5.	Flakiness Index Test (IS:2386 Part 1)	-do-
6.	Bitumen Stripping of Aggregate Test (IS:6241)	-do-
7.	Water Absorption (IS:2386 Part 3)	-do-

10.19.5.2. Tests During Construction

The quality control tests to be carried out during construction are indicated in Table: 10.39

Table: 10.39. Quality Control Tests during Construction

Sl.No	Type of Test	Frequency
1.	Rate of spread of binder	At least two tests per day
2.	Rate of Spread of aggregate (Annex - IV)	-do-
3.	Grading of Aggregate (IS:2386 Part 1)	At least one test per day
4.	Temperature of binder during spraying (Annex - I) intervals.	Regularly, at close
5.	Storage stability Test for Bitumen Emulsion	One test per day
6.	Aggregate impact value (IS:2386-Part 4)	At random one test per km

10.19.5.3. Quality Control Checks by Inspecting Officers

The quality checks to be exercised byInspecting Officers are indicated in Table: 10.40.

Table: 10.40. Quality Control Checks by Inspecting Officers

Sl.No	Type of Test	Frequency
1. Finished Course of Surface Dressing	(i) Uniform spread of aggregate	Whole length
	(ii) Any defects in the form of Loss of Aggregate/ Streaking etc	-do-
	(ii) Surface Regularity and Transverse Profile	Random Checking

10. 20. 20 mm THICK PREMIX CARPET

Quality Control Requirements

10.20.1. Materials

(a) Aggregates

Aggregates shall conform to the physical requirements indicated in Table: 10.41.

Table: 10.41. Physical Requirements of Stone Aggregate

Property	Test	Specification
Particle shape	Flakiness index (IS:2386 Part 1)	Max. 25 %
Strength	Aggregate Impact Value (IS:2386 Part 4)	Max. 30 %
Durability	Soundness (IS:2386 Part Sodium sulphate Magnesium sulphate	Max. 12 % Max. 18 %
Water absorption	Water Absorption (IS:2386 Part 3)	Max. 1 %
Stripping	Coating and stripping of bitumen aggregate mixture. (IS:6241)	Minimum retained coating 95 %

(b) Binder

The binder shall be a penetration grade bitumen of a suitable grade S-65/90 depending on climatic condition of the area or of the type as specified in the Contract.

10.20.2. Horizontal Alignment

The edges of the carriageway with Premix Carpet should be correct within a tolerance limit of (±) 20 mm in plain and rolling terrain and (±) 30 mm in hilly terrain.

10.20.3. Surface Level

The tolerance in surface level of the surface dressing would be (±) 6 mm for machine laid work and (±) 10 mm for work executed manually.

10.20.4. Surface Regularity

The maximum allowable difference between the pavement course and a 3 m straight edge shall not exceed 8 mm for both the longitudinal profile and the cross profile.

10.20.5. Quality Control Tests

10.20.5.1. Tests Prior to Construction The quality control tests to be carried out prior to construction are indicated in Table: 10.42.

Table: 10.42. Quality Control Tests Prior to Construction

Sl.No	Type of Test	Frequency
1.	Quality of Binder (Straight-run Bitumen) (a) Penetration Test (IS:73) (b) R&B Softening Point Test (IS:73) (c) Ductility Test (IS:73)	 One set of tests per lot - do- -do-
2.	Quality of Binder (Bitumen Emulsion) (a) Viscosity (IS:8887) (b) Residue on 600 micron sieve (IS:8887) (c) Storage Stability Test (IS:8887)	 -do- -do- -do-
3.	Quality of Binder (Modified Bitumen) (IS 15462) (a) Penetration Test (b) Softening Point Test (c) Elastic Recovery Test (d) Separation Test	 -do- -do- -do- -do-
4.	Aggregate Impact Value Test (IS:2386 Part 4)	One test per km length on representative sample from each source identified by the Contractor
5.	Flakiness Index Test (IS:2386 Part 1)	-do-
6.	Bitumen Stripping of Aggregate Test (IS:6241)	-do-
7.	Water Absorption (IS:2386 Part 3)	-do-

10.20.5.2 Tests During Construction

The quality control tests to be carried out during construction are indicated in Table: 10.43.

Table: 10.43. Quality Control Tests during Construction

Sl.No	Type of Test	Frequency
1.	Grading of Aggregates (IS:2386 Part 1)	At least two tests per day
2.	Binder Content before seal coat	At least two tests per day
3.	Temperature of Binder	Regular close intervals
4.	Thickness of layer	Regularly at close intervals
5.	Aggregate impact value (IS:2386-Part 4)	At random one test per km

10.20.5.3 Quality Control Checks by Inspecting Officers

The quality checks to be exercised by Inspecting Officers are indicated in Table: 10.44.

Table:10.44. Quality Control Checks by Inspecting Officers

Stage	Test	Frequency
1. Finished Pre Mix Carpet Surfacing	(i) Binder Content before providing seal coat	One test for every 500 m length of the layer
	(ii) Visual inspection of finished surface	Full length
	(ii) Surface Regularity and Transverse Profile	Random Checking

10.21. MIX SEAL SURFACING

Quality Control Requirements

10.21.1. Materials

(a) Aggregates

(i) Physical Requirements:

Coarse aggregate shall conform to the physical requirements indicated in Table10.41. The fine aggregates shall be crushed rock, quarry sand, natural gravel/ sand or a mixture of both free from organic and deleterious substances.

(ii) Aggregate Grading:

The combined coarse and fine aggregates shall conform to one of the gradings given in Chapter 4.

10.21.2. Horizontal Alignment

Surface levels, surface regularity and quality control tests and frequencies shall be exercised as per the requirement given in section 19.

10.22. SEAL COAT

Quality Control Requirements

10.22.1. Materials

(a) Aggregates

Aggregate shall conform to the physical requirements indicated in Table: 10.41. Quantities and grading requirements for aggregates are given in Chapter 4.

10.22.2. Quality Control Tests

The quality control tests and their frequencies would be as per Tables:10.38 and 10.39. for Type A Seal Coat and Table: 10.42 and 10.43. for Type B and C.

10.23. MODIFIED BITUMEN

10.23.1. Quality Control Requirements

1. The modified Binder shall be subjected to the essential tests for quality control before and during execution. The minimum requirements are indicated in Table: 10.45 to 10.48.

Table: 10.45. Requirements of Polymer Modified Binders (PMB) (Elastomeric Thermoplastic Based)

Designation	Grade and Requirements			Method Test
	PMB 120	PMB 70	PMB 40	
Penetration at 25°C, 0.1 mm, 100 g, 5 sec	90 to 150	50 to 90	30 to 50	IS:1203-1978
Softening Point (R&B),°C, Minimum	50	55	60	IS:1205-1978
Elastic Recovery of half thread in ductilometer at 15°C, %, minimum	75	75	75	
Separation, Difference in softening point, R&B, °C, maximum	3	3	3	

Test Procedure outlined in IRC:SP:53-2002

Table: 10.46. Requirements of Polymer Modified Binders (PMB) (Plastomeric Thermoplastic Based)

Designation	Grade and Requirements			Method Test
	NRMB 120	NRMB 70	NRMB 40	
Penetration at 25°C, 0.1mm, 100 g, 5 sec	90 to 150	50 to 90	30 to 50	IS:1203-1978
Softening Point (R&B),°C, Minimum	50	55	60	IS:1203-1978
Elastic Recovery of half thread in ductilometer at 15°C, %, minimum	50	50	50	
Separation, Difference in softening point, R&B, °C, maximum	3	3	3	

Test Procedure outlined in IRC:SP:53-2002

Table: 10.47. Requirements of Natural Rubber Modified Binders (NRMB)

Designation	Grade and Requirements			Method Test
	NRMB 120	NRMB 70	NRMB 40	
Penetration at 25°C, 0.1mm, 100 g, 5 sec	90 to 150	50 to 90	30 to 50	IS:1203-1978
Softening Point (R&B),°C, Minimum	50	55	60	IS:1205-1978
Elastic Recovery of half thread in ductilometer at 15°C, %, minimum	50	40	30	
Separation, Difference in softening point, R&B, °C, maximum	4	4	4	

Test Procedure outlined in IRC:SP:53-2002

Table: 10.48. Requirements of Crumb Rubber Modified Binders (CRMB)

Designation	Grade and Requirements			Method Test
	CRMB 50	CRMB 55	CRMB 60	
Penetration at 25°C, 0.1 mm, 100g, 5 sec	< 70	<60	<50	IS:1203-1978
Softening Point (R&B), °C, Minimum	50	55	60	IS:1205-1978
Elastic Recovery of half thread in Ductilometer at 15 °C, %, minimum	50	50	50	
Separation, Difference in softening point, R&B, °C, maximum	4	4	4	

Test Procedure outlined in IRC:SP:53-2002

Table: 10.49. Essential Tests and their Frequency

Test	Test Method	Frequency
Quality of Binder	Penetration IS:1203· Softening Point IS:1205· Elastic Recovery IS:15462-2004· Separation IS:15462-2004	One Test per lot of 10 tonnes for each source.

MAINTENANCE OF ROADS

11. MAINTENANCE OF RURAL ROADS

11.1. INTRODUCTION

Road maintenance is routine work performed to upkeep the pavement, shoulders and other facilities provided for road users, as nearly as possible in constructed conditions under normal traffic and forces of nature. Maintenance is essential to get optimum service from the pavement structure during its life period. All pavements require maintenance as they are subjected to traffic and environmental effects. Maintenance helps in preserving the pavement surface, and prevents untimely rehabilitation. There are proven maintenance methods, which are applicable to the different regions of the country.

11.1.1. Causes of Deterioration :

A road pavement deteriorates in its level of serviceability with age, basically due to the following factors:

(a) Traffic : The traffic operating on the roads can cause different types of distress like ravelling, rutting, corrugations, cracking, loss of material, loss of skid-resistance and structural deformation. The extent of deterioration depends upon the intensity of traffic, especially wheel load and its repetitions. Solid-wheeled cart traffic can be significant in the case of water-bound macadam roads and earthen roads.

(b) Environment : The external influence of environmental factors such as rainfall, snowfall, temperature variations and atmospheric conditions can also cause deterioration of the pavement. Rainfall causes erosion of shoulders and slopes and ingress of water into the pavement structure and subgrade and affects the performance of drainage structures. Snowfall can cause ingress of moisture into the pavement structure and subgrade and result in frost action. It can also disrupt traffic. Temperature variations can adversely affect the performance of bituminous surfaces and cement concrete pavements. Atmospheric action can oxidize the binder and cause deterioration.

In addition to the above, the extent of deterioration and its rate are governed by the standards to which a road was designed initially. If a road is designed to higher standards initially, its maintenance needs will be lower than for the road designed to lower standards initially.

11.1.2 MAINTENANCE ACTIVITIES

Maintenance activities are divided into two categories.

Preventive Maintenance:

Preventive Maintenance includes repair of small sized pot holes, crack sealing, maintenance of shoulders, drainage systems etc.

Corrective Maintenance:

Corrective Maintenance includes patch repairs, surface treatments and surface renewals and overlays.

11.1.3 CLASSIFICATION OF MAINTENANCE ACTIVITIES

As per IRC: 82 maintenance activities can be classified as:

1. **Routine Maintenance** such as pot hole filling, filling the cracks etc. round the year.
2. **Periodic Maintenance** covering renewals, which are required to be done at periodic interval every few years.
3. **Rehabilitation and strengthening**, which includes major restoration or upgrading of pavement through reconstruction or application of overlays to structural deficiencies.

11.1.4. MAINTENANCE OF SHOULDERS, DRAINAGE & STRUCTURES

Inspection of drainage system, shoulders etc in both dry and rainy seasons is necessary for effective identification of various defects. In the dry season, structural damages can be better identified and in the rainy season, actual functioning of the drainage system can be evaluated. Any field engineer must evaluate the extent of damage in order to quantify the needed maintenance measures; such an evaluation can best be done by inspection on foot. The engineering staff should look for :

(i) Ditch cross-action destroyed

(ii) Ponding in the ditch and shoulders

(iii) Silting

(iv) Uneven ditch invert, varying x-section

(v) Invert and sides of ditch eroded

(vi) Drain destroyed

(vii) Ditch lining damaged

(viii) Ponding/ erosion

The common defects, their causes and measures needed for rectification are given in Table 11.1.

Table : 11.1

Sl. No.	Defects	Cause	Maintenance Measures
1.	Ditch cross section destroyed	Plying of vehicles/ movement of animals	Reshaping/ Regrading of ditch
2.	Ponding in ditch and on shoulder	Insufficient ditch x-section	Deepening of ditch
3.	Silting of drain	Water flows slowly on the invert slope	Desilting of ditch
4.	Uneven ditch invert	Blockage caused by debris/ vegetation	Clearing, cleaning and regrading
5.	Erosion of sides and bottom of ditch	Too steep gradient	Reinforcing of ditch slopes, regrading or realignment of drain, ditch checks
6.	Destruction of lined or precast drain	Poor alignment or change in flow direction	Erosion control and realignment of drain
7.	Ditch lining is damaged	Settlement/ erosion of soil under ditch	Erosion repair and lining repair
8.	Ponding, erosion	In-sufficient lateral drainage	Provision of lateral drainage
9.	Silting, blockage by debris of culvert	Too flat gradient, in-correct positioning of culvert Floating debris lodged in culvert	Clearing and cleaning and provision of debris rack.
10.	Erosion of stream bed at culvert outlet	Water flow very fast/ culvert invert on a flat grade	Erosion repair
11.	Settlement cracks on the culvert	Settlement of soil below	If minor cracks, only repair of cracks. In case of major settlement the culvert must be reconstructed.
12.	Rusting of steel in culvert	Weathering, poor quality material	Repair of steel section
13.	Cracks in paved surface of causeways	Settlement	Sealing of cracks
14.	Obstruction on shoulders	Operational	Removal of obstruction
15.	Level of shoulders higher than carriageway	Transportation of carriageway material by traffic, swelling of soils, vegetation growth.	Regrading of shoulders and surface vegetation control.
16.	Ruts and depressions in shoulder	Erosion, plying of vehicles	Patch work and reshaping
17.	High vegetation on shoulder	Unchecked growth of vegetation	Vegetation control
18.	Level of shoulder lower than carriageway	Erosion/ settlement of carriageway	Replenishment of shoulder
19.	Vegetation overgrowth on slopes	Lack of grass cutting, trimming	Vegetation control
20.	Erosion of slopes due to surface water	Rain water accumulation at the top of the slopes	Erosion repair by cut off ditch, collector drains, chutes, berms, vegetation cover and masonry protection

Activities

Reshaping/ Regrading/ Deepening of Ditches/ Drains :

These can be done manually. Alignment should be set by string line and the materials within the string line should be cut and removed. Cross section, grading and depth should be checked and corrected. Wherever possible, motor grader can be used for these activities. The excess material must be removed from site and in no case should be spread on the road surface.

Clearing and Cleaning of Ditches/ Drains :

Any object which can interfere with water flow should be removed. These objects should be disposed of well away from the road so that these cannot impede the water flow again.

Repair of Drain Erosion :

This should be done by replacing and back filling the lost soil. Permanent measures like masonry lining or precast drain can be considered.

Repair of drain lining :

Settled or damaged precast sections or loose stone should be removed and underlying soil compacted. After addition of fresh soils, the levels should be corrected and then only fresh stones or precast drain should be laid.

Vegetation control :

Except in arid areas once a year, grass and weed cutting and bush clearance on the shoulders is a must. In case of earth or gravel roads these activities may be required to be done more frequently. Tractor-towed mower can be employed where available, but ordinary manual method should be sufficient for the purpose. Dead or leaning trees should be removed from the roadside. Use of chemicals or burning of the roadside vegetation should be avoided as these are harmful.

11.1.5 MAINTENANCE OF EARTHEN ROADS

Earth roads form a major percentage of rural roads in India and hence their efficient maintenance is of great importance. Because of the low specifications (inadequate embankment height, small roadway width and low cost drainage arrangements), good maintenance can preserve the assets and prolong their life. The principal maintenance operation consists of maintaining the cross-section by grading and dragging.

Activities

Grading

The shaping and sectioning of an earth road is best done by blading with a grader or motor grader. A grader of about 110 HP is suitable for the purpose. In India, it is most unlikely that mechanical graders would be available for routine maintenance operations for low volume roads. Manual methods should include making up of ruts and deformation by additional soil from borrow pits and restoring the camber. If solid-wheeled traffic is heavy and ruts are formed, the ruts can be filled by quarry run, gravel or other local materials.

Dragging

Dragging rectifies to an extent, the formation of corrugations. A typical drag can be towed by animal power, by men or by motor grader.

Rolling

The earth surface should be rolled and compacted after grading and dragging. A light sprinkling of water needs to be done if rolling is done in dry season.

Filling of rain-cuts

Rain-cuts in the embankment slopes should be filled up after the rainy season. Turfing prevents soil erosion.

11.1.6 MAINTENANCE OF UNSURFACED ROADS : GRAVEL/ SOIL-GRAVEL/ WBM ROADS

An unsurfaced road might be a gravel road or water bound macadam road. The maintenance of these roads actually would depend on the surface course material and the subgrade soils/ climatic conditions. Since the level of serviceability acceptable in rural roads would relatively be lower, the maintenance measures should be so designed as to maintain the road to atleast the minimum acceptable level of serviceability.

The more common defects encountered in unsurfaced roads are :

(i) Loss of shape
(ii) Ruts
(iii) Potholes

(iv) Corrugations
(v) Erosion gullies
(vi) Blocked ditches
(vii) Ravelling in case of WBM surface

Defects, their causes and remedial measures needed

Loss of shape :

The earthen and gravel roads under traffic and under the action of natural elements, like water and wind slowly lose their surface camber. And with the loss of camber, surface drainage is inhibited causing ponding of accumulated rainwater. It is thus essential to maintain the road surface to the proper camber, necessary for draining out the surface water. The shape of road surface can be rectified by an ordinary motor grader. The material should be returned from the sides to centre so as to restore the camber. Alternatively, manual methods of restoring the camber can be resorted to, with the help of pickaxe and spades. The graded surface should be brought to correct moisture content and rolled by a power roller.

Corrugations :

Earthen roads and gravel roads develop wavy formations in the longitudinal direction. The frequency and height of these corrugations depend on many factors. These can be removed by motor grader; alternatively manual methods can be adopted.

Potholes, Ruts, Soft Spots and Erosion Gullies :

These defects are of most common occurrence in earthen roads. Patch repairing work should be resorted to, for the correction of these defects. Soft spots may be due to the accumulation of rainwater or due to the presence of soft soil underneath. In the first case, removal of water from the surface will rectify the defects but in case of latter, the opening and drying (and if necessary removal) of soft soil would be required. Patch repairing work followed by compaction by hand rammer is advisable only if the extent of these damages is not severe. But in case of extensive damage, regravelling (with needed rectification in the subgrade layer) should be resorted to. In case of patch repairing, all loose materials and water should be removed and appropriate quality materials at correct moisture content should be placed on the scarified surface and rammed at least 3cm proud of the remaining areas. In all these cases, special attention should be paid to road side shoulders. Shoulders should be properly attended to for ensuring proper drainage of surface water.

Potholes and Ravelling in WBM Surface :

Ravelling is a phenomenon common to old WBM surface or improperly constructed WBM layer. It may be due to excessive plastic binding material in rainy season where both potholing and raveling may take place. Or it might be due to the presence of non-plastic filler. The raveling, if extensive, should be rectified by following the procedure of remetalling to the extent needed. The loose stone aggregates on the road surface may be supplemented from the aggregate stock. Power road roller should be used for compaction. In case of minor potholes and raveling, patch repairing should be resorted to.

Defects, their causes and rectification measures needs for unsurfaced roads are summarized as under:

Table : 11.2

Sl. No.	Defects	Cause	Maintenance Measures
1.	**Earthen/ gravel roads** (a) Loss of shape	Traffic; Natural elements	Grading by motor graders or manually in dry condition, wetting the loose material and compaction by power roller.
	(b) Corrugations	Materials; traffic	Grading (as above)
	(c) Ruts	Iron rimmed carts	Patch repairing in case of minor defects. Severe and extensive damages should be rectified by regravelling.
2.	**WBM Roads** (a) Potholes	Substandard aggregates; excessive plastic filler in rainy season	Patch repairing in case of minor defects.
	(b) Ravelling	Traffic; substandard construction;	excessive plastic filler in rainy season; non-plastic filler in dry areas. Remetalling in case of extensive damage.
3.	**Roadside Drains & Ditches**		As suggested in para 2.2.

Activities

Grading :

The main purpose of grading is to restore the pavement and shoulder surface to their original cambers by returning the materials from the sides and shoulders to the centre. The grading should be done just after rains so that the retrieved material can be properly compacted. The grading should be operated over longer length say about 100 meters at a time. Rolling should be done immediately but only after the grading in a particular stretch has been completed. Junctions and bends should be carefully

graded. When side ditches are to be reshaped, it should be tackled at the same time but before the shoulders and carriageway are graded. No materials from the side drain should be deposited on shoulders/ carriageway.

Patching :

The gravel/ soil used in the original work should be, as far possible, used in patching work. The affected area should be cleaned of all loose material and brought to some regular shape preferably rectangular by chiselling. Once the material has been removed the bottom surface should be compacted with hand rammer. Gravel/ soil at required moisture content should then be placed uniformly over the area (with 1/3rd extra thickness). The camber and gradient of the large patch works should be checked before it is properly compacted. The hand feel method of estimating the moisture can be adopted.

Regravelling:

Gravel roads require regravelling after certain periods of time, depending on the traffic and climatic conditions. The supervisor should plan the regravelling well in advance so that the work is carried out before serious defects appear. Regravelling should be done in one layer of atleast 10cm compacted thickness. Before the work is executed, the road surface should be properly graded to camber and gradient.

The edges should be boxed to provide lateral support for the new layer and the base should be firm. For gravelling, the adequate quality of gravel should be selected and the optimum moisture content determined. In case of non-availability of laboratory facilities, handfeel method can be adopted. After the required thickness of gravel has been spread over the firm base to camber and gradient, watering should be done by a water tanker, and mixed by rotavator or manually. Alternatively, gravel should be watered on the roadside stacks and mixed manually before laying on the carriageway. Compaction should be done by 8-10 tonne power roller normally. Alternately, lighter roller can be used with adjustment of layer thickness. Compaction should be checked as per normal procedure.

11.1.7 MAINTENANCE OF BITUMINOUS SURFACES

Defects, Symptoms, Causes and Remedies

A bituminous surface wears out due to (i) traffic (ii) weather, such as ingress of water, loss of volatiles in the binder and oxidation of binder (iii) inadequacies in the initial specifications and construction standards. Table 1 lists out for each type of distress, symptoms, probable causes and possible types of treatments (IRC).

Symptoms, causes and treatment of defects in bituminous surfacings is given in Table 11.3

Table 11.3

Types of Distress	Symptoms	Probable Causes	Possible types of treatment
A. Surface defect			
1. Fatty surface	Collection of binder on the surface	Excessive binder in premix, spray or tack coat; loss of cover aggregates, excessively heavy axle load.	Sand-blinding; open-graded premix; liquid seal coat; burning of excess binder; removal of affected area.
2. Smooth surface	Slippery or excessive binder.	Polishing of aggregates under traffic, Resurfacing with surface dressing or premix carpet.	
3. Streaking	Presence of alternate lean and heavy lines of bitumen	Non-uniform application of bitumen, or at a low temperature.	Application of a new surface.
4. Hungry surface	Loss of aggregates or presence of fine cracks	Use of less bitumen or absorptive aggregates	Slurry seal or fog seal.
B. Cracks			
1. Hair-line cracks	Short and fine cracks at close intervals on the surface	Insufficient bitumen, excessive filler or improper compaction.	The treatment will depend on whether pavement is structurally sound or unsound. Where the pavement is structurally sound, the cracks should be filled with a low viscosity binder or a slurry seal or fog seal depending on the width of cracks. Unsound cracked pavements will need strengthening or rehabilitation treatment.
2. Alligator cracks	Inter-connected cracks forming series of small blocks.	Weak pavement, unstable conditions of subgrade or lower layers, excessive overloads or brittleness of binder.	
3. Longitudinal cracks	Cracks on a straight line along the road	Poor drainage, shoulder settlement, weak joint between adjoining spreads of pavement layers or of differential frost heave.	
4. Edge cracks	Cracks near and parallel to pavement edge	Lack of support from shoulder, poor drainage, frost heave, or inadequate pavement width	
5. Shrinkage cracks	Cracks in transverse direction or inter-connected cracks forming a series of large blocks.	Shrinkage of bituminous layer with age.	
6. Reflection cracks	Sympathetic cracks over joints and cracks in the pavement underneath.	Due to joints and cracks in the pavement layer underneath	
C. Deformation			
1. Slippage	Formation of crescent shaped cracks pointing in the direction of the thrust of wheels	Unusual thrust of wheels in a direction, lack or failure of bond between surface and lower pavement courses.	Removal of the surface layer in the affected area and replacement with fresh material.
2. Rutting	Longitudinal depression in the wheel tracks	Heavy channelised traffic, inadequate compaction of pavement layers, poor stability of pavement material or heavy bullock cart traffic.	Filling the depressions with premix material.
3. Corrugations	Formation of regular undulations	Lack of stability in the mix, oscillations set up by vehicle springs, or faulty laying of surface course.	Scarification and relaying of surfacing, or cutting of high spots and filling of low spots.

Types of Distress	Symptoms	Probable Causes	Possible types of treatment
4. Shoving	Localised bulging of pavement surface alongwith crescent shaped cracks	Unstable mix, lack of bond between layers, or heavy start-up type movements and those involving negotiations of curves and gradients.	Removing the material to firm base and relaying a stable mix.
5. Shallow depression	Localised shallow depressions	Presence of inadequately compacted pockets.	Filling with premix materials.
6. Settlement and upheaval	Large deformation of pavement	Poor compaction of fills, poor drainage, inadequate pavement or frost heave.	Where fill is weak the defective fill should be excavated and redone. Where inadequate pavement is the cause, the pavement should be strengthened.
D. Disintegration			
1. Stripping	Separation of bitumen from aggregates in the presence of moisture	Use of hydrophilic aggregates, inadequate mix composition, continuous contact with water, poor bond between aggregate and bitumen at the time of construction etc.	Spreading and compacting heated sand over the affected area in the case of surface dressing, replacement with fresh bituminous mix with added anti-stripping agent in other cases.
2. Loss of aggregate	Rough surface with loss of aggregate in some portions.	Ageing and hardening of binder and aggregate, poor compaction etc.	Application of liquid seal, fog seal or slurry seal depending on the extent of damage.
3. Ravelling	Failure of binder to hold the aggregates shown up by pock marks of eroded areas on the surface.	Poor compaction, poor bond between binder and aggregate, insufficient binder, brittleness of binder etc.	Application of cutback covered with coarse sand, or slurry seal, or a premix renewal coat.
4. Pot-hole	Appearance of bowl-shaped holes, usually after rain	Ingress of water into the pavement, lack of bond between the surfacing and WBM base, insufficient bitumen content etc.	Filling pot-holes with premix material, or penetration patching.
5. Edge-breaking	Irregular breakage of pavement edge.	Water infiltration, poor lateral support from shoulders, inadequate strength of pavement edges, etc..	Cutting the affected area to regular sections and rebuilding with simultaneous attention paid to the proper construction of shoulders.

11.1.8. Pot-Hole Repair (Patch Repair)

The amount of patching needed to make up pot-holes and localized failures may vary from 0 to 25 per cent of the surface area annually. Patching prolongs the surface life until a time will come when it will be more economical and desirable to renew the surface entirely.

Patching can be done by (i) sand premix, (ii) open-graded premix (iii) dense-graded premix (iv) penetration patching or (v) surface dressing. Dense-graded premix patch is rarely used, only where the existing surface itself is dense-graded asphaltic concrete. Surface dressing (one or two coats) can be done for existing surfaces with a similar specification and where the traffic is not too heavy.

Patching consists of the following sequence of operations

1. Clearing the area by brooming
2. Trimming the sides vertically and the shape to a rectangle or square and making the bottom level.
3. Painting the sides and bottom of the hole with a tack coat if a premixed material is used.
4. Following the regular specifications of the treatment
5. Rolling or hand tamping and checking the profile with straight edge.

Sealing the surface is resorted to rectify hungry surface, repair cracks, and arrest loss of aggregates. Sealing can take the form of the following treatments:

1. Liquid Seal
2. Fog seal
3. Slurry seal

Liquid seal is an application of a binder (penetration grade or emulsion) at 9.8 kg/ 10 sqm followed up with a spread of cover aggregates, 6.3 mm nominal size, at a rate of 0.09 cum/10sqm and rolling in position.

Fog seal is a spray of slow-setting emulsion diluted with equal amount of water at a rate 0.5-1 litre per sqm. Traffic is allowed after the seal sets in. It is provided over a hungry surface, a cracked surface, a surface where there is loss of aggregates and over a surface exhibiting raveling.

Slurry seal is an application of a slurry composed of slow-setting emulsion, water and aggregates to a thickness of 5-10 mm. The emulsion and water are 18-20 percent and 10-12 percent respectively of the weight of aggregates. The slurry is spread at the rate of 200 sqm per tonne. No rolling is needed. Slurry seal is provided over a hungry surface, cracked surface, a surface where there is loss of aggregates and over a surface exhibiting raveling. Because of low viscosity of the binder, the specification results in sealing voids and cracks.

When patching becomes too high, it is more economical to renew the surfaces with suitable treatments which include : Metal Renewal 75 mm (MR-I); Single coat or Double-coat Surface Dressing (SD-I or SD-II); Premix Chipping Carpet with Seal Coat (PC + SC);

Mix Seal Surfacing (MSS); Semi-Dense Bituminous Concrete (SDBC) or Bituminous Concrete (BC).

Such renewals are part of preventive maintenance and prolong the life of a pavement. These renewals result in a better riding quality when the surface has deteriorated.

The type and periodicity of such renewals are given in Table 11.4.

Life Cycle (In years) for MDR/ODR/VR

Table 11.4

Type of Treatment/ Category of Road	Traffic Intensity in CVD	MR-I	**SD-I/ SDII	PC+SC	20 mm MSS	25 mm SDBC	25 mm BC
MDR/ODR/ VRNormal	> 1500	–	–	–	–	5/4*	5/4*
	450-1500	–	–	–	–	5/4*	–
	150-450	–	–	–	5/4*	5/4*	–
	< 150	5/4*	5/4*	5/4*	–	–	–
MDR/ODR/ VR(Urban)	> 1500	–	–	–	–	4/3*	4/3*
	450-1500	–	–	–	4/3*	4/3*	–
	150-450	–	3	4/3*	4/3*	–	–
	< 150	3	4/3*	5/4*	5/4*	–	–
MDR/ODR/ VR(Hills)	> 1500	–	–	–	–	4/3*+	4/3*+
	450-1500	–	–	–	–	5/4*+	5/4*+
	150-450	–	3	5/4*	5/4*+	–	–
	< 150	4/3*	4/3*	5/4*	–	–	–

Note* : A. Indicates reduced life of treatment due to high rainfall i.e. > 3000 mm.

B. + Indicates reduced life due to higher altitude i.e. > 2000 Mts.

C.** The treatment of SD-I to be used under condition of severe resource crunch only .

11.2 MAINTENANCE OF CEMENT CONCRETE SURFACE

A well designed and properly constructed cement concrete pavement needs hardly any maintenance. In fact, this is one of the strong points of this specification. However, defects do appear due to the following reasons :

1. Ingress of water to the subgrade causing uneven settlement especially through joints.
2. Inadequate design and faulty workmanship

Cracks

A common defect noticed in a cement concrete slab is the appearance of cracks. Cracks can be shrinkage cracks, structural cracks, construction cracks, corner cracks and warping cracks. They can be of varying width. Usually hair cracks are not dangerous since they do not admit water to the subgrade. Medium and wide cracks are harmful since they can cause progressive destruction of the subgrade support by allowing water to percolate. Such medium and wide cracks are filled up by liquefiable substances such as bituminous emulsions, cutback bitumens or joint sealing compounds, whose basic ingredient is bitumen. Before the cracks are sealed, they are cleaned of dust and foreign matter. Compressed air jets and nozzles are useful to achieve this. The dry joints are then filled with appropriate bituminous binder poured by cans. The poured material is topped up with sand or fine chips to prevent the removal of binder under traffic.

Joints

The maintenance of joints consists in examining whether the joints are properly sealed and if not, to immediately seal them. If the preformed joint filler has rotted and deteriorated, it should be removed and substituted by a fresh compressible filling material. The sealing material is then poured.

Patching of Slabs

A variety of defects such as sealing, spalling, depressions, irregularities and failures, can occur locally in a slab. In such cases, it is necessary to patch up the defective portions immediately to arrest further deterioration. Bituminous premix materials though very widely used for this purpose are not very satisfactory. The best materials are concrete, and epoxy/ polyester resin mortars. Such patches are of

regular geometrical shapes, without acute-angled corners. The sides are first trimmed and made vertical and fresh concrete is laid and tamped.

Mud-pumping and blowing

When the subgrade becomes moist with free accumulation of water, heavy axle loads passing over the slab will eject water and mud through the joints, cracks and pavement edges. This phenomenon is known as mud-pumping and blowing. When a pavement exhibits this phenomenon, the joints and cracks should be inspected and defective ones refilled and sealed. A bituminous underseal can be pumped underneath the slab to prevent recurrence of the defect. This is accomplished through drilled holes in the slab. A viscous binder is preferred. This fills voids in-between the slab and the subgrade.

Loss of Texture

If the surface becomes smooth and slippery, texture can be restored by cutting grooves by machines. Acid etching can also be adopted.

11.2.1 MAINTENANCE OF SLOPES OF EMBANKMENTS

Embankment slopes get easily damaged due to rains. Raincuts, unless properly attended to in time, erode the slopes right upto the pavement edges and damage the pavement ultimately. Turfing is one of the easiest and most effective ways of maintaining the slopes. Turfing checks erosion and improves the aesthetics of the road vastly. Turf should be mowed periodically, preferably before the monsoons.

The slopes of embankments subjected to inundation and flooding are protected often with boulder pitching. They tend to get dislodged due to slips and settlements. The damaged stones should be removed, the slopes made up and pitching redone with adequate granular bedding.

11.3 MAINTENANCE OF BRIDGES AND CULVERTS

11.3.1 Bridge and Culvert Register

The maintenance of bridges and culverts is greatly facilitated if a register containing the salient features of structures is maintained. The structures should be numbered as per standard practice. Thus, a number 343/3 would indicate that the structure is the third in the 343rd kilometre. The number should be painted prominently on the parapet of the structure. The register should give particulars such as :

1. Number of structure
2. Date of construction
3. Type of structure
4. Waterway (number and length of spans)
5. Foundation particulars
6. Behaviour of structure during floods (HFL to be indicated)
7. History of periodic maintenance (painting, pointing of masonry, regirdering etc)

Periodic Inspection

The structures should be periodically inspected at least once in a year by (1) Junior Engineers in case of culverts of waterway upto 6m (2) Assistant Engineers in case of minor bridges (Length 6-30m), Executive Engineers in case of medium bridges (length 30-150m) and Superintending Engineers in case of major bridges (length greater than 150m).

The following points should be noted during inspection :

1. Condition of foundations, and any signs of scour
2. Condition of substructure and any signs of damage
3. Condition of floor protection works, and signs of scour and dislodgement
4. Bearings : greasing, tilts, signs of corrosion
5. Superstructure : signs of cracks, corrosion
6. Condition of painting of steel girders
7. Signs of settlement
8. Condition of wing walls
9. Condition of guide bunds

10. Condition of approaches
11. Condition of wearing coat, hand rails, approach slabs, curbs, drainage spouts and guard stones.
12. HFL reached
13. Condition of river channel and its banks
14. Adequacy of the opening
15. Condition of pipes in a pipe culvert and minimum cushion

Painting of Steel Bridges

Steel members get corroded unless protected by painting. Painting should be done once in 6 to 12 years, depending on location and nearness to sea.

Maintenance of Masonry

Repointing of joints of brick and stone masonry should be done if deterioration is noticed. All vegetable growth should be cleared. Roots of trees which are likely to cause disruption of the masonry of abutments and wing walls should be cleared. Weepholes of abutments and wing walls should not be allowed to clog.

Scour

Control of scour of foundation can be obtained by dumping boulders, construction of spurs and dumping a garland of concrete blocks or stone sausages around piers. Scour meters provide good information on the extent of scour.

Bearings

Metallic bearings deserve special attention. They should be cleaned and greased with a natural graphite grease.

Expansion Joints

Expansion joints get dislodged and loosened frequently. They should be immediately restored.

Weak and Narrow Structures

Rating of bridges and culverts should be done periodically and the safe load displayed prominently on the structures.

11.4 SPECIAL PROBLEMS OF HILL ROAD MAINTENANCE

Some of the special problems of hill road maintenance are :

1. Snow clearance
2. Slips and landslides
3. Drainage

Snow Clearance

The roads in the Himalayan hill region get covered with snow. Snow clearance can be done manually or by special equipment (dozers, snow masters and snow blasts).

Landslides and Slips

Landslides and slips are a common feature of hill roads. Road maintenance in areas subjected to landslides and slips poses severe problems. The greatest of them is quick removal of debris and restoration of traffic. Mechanical equipment like dozers become very necessary.

Drainage Maintenance

Maintenance of drainage structures is an important task in hill road maintenance. The quick and efficient removal of water prevents slips and landslides and road deterioration. Drainage arrangements such as catchwater drains, cross-drainage structures, side drains and subsurface drains should be inspected before the monsoons and cleared of all obstructions.

11.5 Condition Rating in Terms of Present Condition Index (PCI)

The most simple rating scale for the Present Condition Index, is roughly derived from the speed of travel, as under :

Table 11.5

Normal Driving Speed	PCI
Over 40 km/hr	5
30 to 40 km /hr	4
20 to 30 km/hr	3
10 to 20 km/hr	2
Less than 10 km/hr	1

Alternatively, the riding comfort observed when driving at a design speed of 50 km/hr can be assessed as under :

Riding Comfort @ 50 km/hr	PCI
Smooth and Pleasant Ride	5
Comfortable	4
Slightly Uncomfortable	3
Rough and Bumpy	2
Dangerous	1

The PCI can also be assessed on a visual inspection of the surface condition as under :

Riding Comfort @ 50 km/hr	PCI
Very Good	5
Good	4
Fair	3
Poor	2
Very Poor	1

11.6 Prioritisation of Maintenance Interventions

The following prioritisation scheme for maintenance intervention may be adopted.

Table : 11.6 Prioritisation of Maintenance Intervention

	PIC	
(i) Reconstruct immediately	$\leq$ 1.0	Pavement is in very poor condition with extensive severe cracking, alligatoring, potholing and depressions. Ridability is very poor and the surface is very rough and uneven.
(ii) Reconstruct within 1 year	1.0 to 1.5	Pavement is in poor to very poor condition with moderate alligatoring and extensive severe cracking, potholing and depressions. Ridability is poor and the surface is very rough and uneven.
(iii) Reconstruct in 1-2 years	1.5 to 2.0	Pavement is in poor condition with frequent moderate alligatoring and extensive moderate cracking, potholing and depressions. Ridability is poor and the surface is rough and uneven.
(iv) Reconstruct in 2-3 years or resurface in 1-2 years.	2.0 to 2.5	Pavement is in poor to fair condition with frequent moderate cracking, potholing and depressions and intermittent moderate alligatoring. Ridability is poor to fair and surface is rough and uneven.
(v) Resurface in 2-3 years	2.5 to 3.0	Pavement is in fair condition with intermittent moderate and frequent slight or moderate alligatoring, potholing and depressions. Ridability is fair and surface is moderately rough and uneven.
(vi) Resurface in 3-5 years	3.0 to 3.5	Pavement is in fairly good condition with slight cracking, slight or very slight potholing and a few areas of slight alligatoring. Ridability is fairly good with intermittent rough and uneven sections.
(vii) Normal maintenance only	3.5 to 4.0	Pavement is in good condition with frequent very slight or slight cracking. Ridability is good with a few slightly rough and uneven sections.
(viii) No maintenance required	> 4.0	Pavement is in very good condition may be with few hairline cracks. Ridability is very good, may be with few areas of slight distortion.

ROAD SAFETY

12. ROAD SAFETY

12.1 Background

The traffic on most existing earthen tracks and substandard existing links consists mainly of bicycles, some two-wheelers, some animal-drawn vehicles and a few agricultural tractors. The construction of new links to hitherto unconnected habitations and upgradation of existing links will generate a considerable amount of motorised traffic on Rural Roads.

The sudden influx of high speed motorised vehicles to the rural roads can severely endanger the safety of road users, particularly of vulnerable road users like children (going to the schools), women carrying headloads of agricultural produce, cyclists etc. The problem gets aggravated because all the road users utilise the same narrow road width of a single lane, where crossing and overtaking becomes very difficult. Moreover, drivers of agricultural tractors, jeeps, light commercial vehicles, two-wheelers and buses in the rural areas are not always given to adequate observance of driving rules and traffic signs. It is thus expected that as the rural roads get constructed and upgraded, road safety will be an issue requiring serious consideration. When accidents do take place, trauma care and other facilities available in hospitals of towns and cities are not within the easy reach of the accident victims. Under these circumstances, preventive measures, both engineering and social, must be taken up to the extent feasible.

12.2 Engineering Measures in the Design phase.

- Rural roads have to necessarily have a tortuous path, keeping in view the narrow land width available. All the same, the horizontal curves should be designed scientifically, conforming to the selected design speed and terrain.
- The horizontal curves must be provided with smooth transition curves and super-elevation. The pavements should be widened at curves.
- The vertical profile of the road should be designed such that the required minimum stopping sight distance is available. Suitable summit and valley curves should be provided.
- In hill roads, blind curves are a safety hazard. Suitable vision berms may be cut at such locations.

- Passing places must be provided at convenient locations particularly on hill roads.
- The provision of rural connectivity leads to the introduction of bus services. Properly designed bus-bays must be provided at bus stop to ensure that the buses do not hamper the normal traffic.
- Where the roads pass through habitations and school, it is necessary that the motorized vehicles travel at low speeds. This can be ensured by providing adequately designed road humps or rumble strips.
- The junction of rural roads with a main road is always a point of conflict and an accident-prone zone. Such junctions must be designed scientifically by providing minimum turning radii, flaring of the side road with taper, acceleration/ deceleration lanes and adequate sight distances.
- Ramps must be provided where field paths and cattle crossings intersect the road.
- Traffic signage, incorporating warning and regulatory signs, can enhance road safety, especially near habitations and school zones, sharp curves, narrow bridges, junctions, submersible bridges and causeways. The design must incorporate these.
- Hazard markers like reflectorized delineators must be provided at dangerous locations.
- Submersible bridges and causeways should be provided with water depth gauges and guide-posts that shall remain at all times above the highest water level.
- 300mm dia ducts should be provided in the embankment to enable cultivators to thread agricultural wise pipes for irrigating their fields lying on both sides of the road.

12.3 Safety during Construction and Maintenance Operations.

Construction zones create an environment where the road user is confronted with sudden obstacles and unfamiliar conditions. Safety in construction zones must be enhanced by:

i. Warning the road users (in the appropriate language) clearly and sufficiently in advance

ii. Providing safe and clearly marked lanes for guiding road users

iii. Providing safe and clearly marked buffer zones and work zones

- Barricades, drums, traffic cones, cylinders and signs around work zones
- Flagmen with red flags positioned to regulate and warn the road users.
- Using construction machinery carefully and parking such machinery at locations where they are not traffic hazards.
- Stacking construction materials such that only the quantity needed for one operation is stacked along the road, and obstruction to road users is minimised.
- Providing well designed temporary diversions as necessary so that the essential traffic moves with the least hindrance. The Contractor shall be asked to provide these as part of his work. The bidding document and specifications shall elaborate these requirements.

12.4. Road Safety During Use

- Routine maintenance of rural roads are regularly carried out.
- All safety issues out of maintenance inspection are properly addressed.
- In all cases of accidents and inquiry/investigation thereof, safety issues are resolved, and a report is made for examination whether standard design features need to be incorporated in other rural roads.

12.5. A detailed guide on road safety.

Before Driving on Roads:

Please ensure to keep the following items before driving on roads in India:

- Driving License
- Certificate of Insurance
- Certificate of Registration
- Pollution Check Certificate

What To Do? (For Four Wheelers)

- Always Wear Seat belts & Ask Co-Passenger to do same.
- Always use Child seats for Children under 4+.
- Allow Pedestrians to Cross the Roads First.
- Allow the Emergency Vehicles (Ambulance, Fire brigade) to pass.
- Use Indicators & rear view mirrors when changing Lanes.
- Slow down while approaching an intersection.
- Always maintain appropriate distance from the vehicle in front.
- Always drive in your lane.

What NOT To Do? (For Four Wheelers)

- Never Jump Any Red Light.
- Never Drink & Drive.
- Never Use Mobile Phones when driving
- Never Drive More than 60 Km/hr. in City.
- Never Drive If you're below age of 18.
- Never Park on Busy Roads.
- Never apply brakes suddenly

What to Do? (For Two Wheelers)

- Always wear a full mask good quality helmet & fasten it.
- Always check the inflation of both front and rear tires.
- Always ensure the front and rear lights are functional.
- Always give proper indications before turning.
- Always use front and rear brakes simultaneously.
- Keep a safe distance from the vehicle ahead.

What NOT to Do? (For Two Wheelers)

- Never ride in a zig-zag manner.
- Never overtake from the blind corners of a vehicle or from the left side
- Never apply brakes suddenly.
- Never carry heavy loads or more than one person as pillion rider.
- Never use cell phone while riding.

Understand the Language of Road:

- **Center Line:** The white broken line divides the road into two, separating opposing stream of traffic. This line can be crossed if overtaking is essential provided the oncoming carriageway is clear
- **Twin White/Yellow Lines:** These lines divide the road into two and crossing them from either side is strictly prohibited.
- **Small Broken White Lines:** They separate the lanes on a road, Vehicles are supposed to move in between these lines and generally left most lane is allotted to HMV.
- **Single Yellow Line:** You cannot cross this line except while turning Right or taking a U-Turn.
- **Zebra Crossing:** Alternate black and white stripes painted are meant for pedestrians to cross the road when signals indicate so. The vehicles must stop and give way to pedestrians at such crossings.

12.6. Road Safety Signs

12.6.1. Road Traffic Signs are of Three Types:

- Mandatory: Marked In a Red Circle
- Cautionary: Marked in a Red Triangle
- Informatory: Generally Marked in Blue

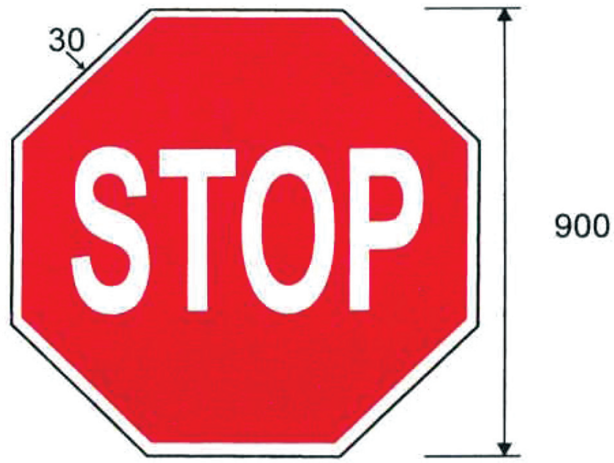
12.6.2 Location of Signs

- **Stop signs** should be fixed 1.5 to 3 metres in advance of the stop line.

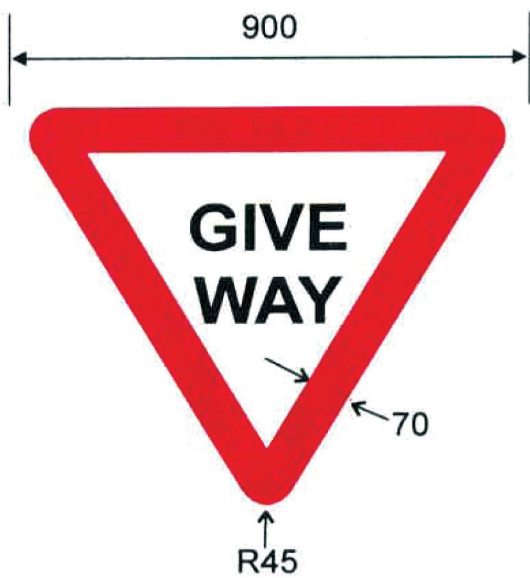
- **Give way sign** should be located in advance to the point where vehicles required to stop to yield the right-of-way, say at a distance of 25 to 50 m.
- **U-turn prohibited sign** shall be erected at the start and at intervals along section of a road. The spacing between any two successive signs should not exceed 120 metres on each side of the road.
- **Overtaking prohibited sign** shall be erected at the beginning of such sections where sight distance is restricted and overtaking will be hazardous.
- **Horn prohibited sign** shall be used on stretches of the road where sounding of horn is not allowed such as near hospitals and in silence zones.
- **No Parking sign** shall be erected where the controlling authority has resolved to prohibit parking.
- **No Stopping / Standing sign** shall be erected on sections of a road or street where the controlling authority has decided to prohibit stopping of vehicles, even temporaily.
- **Speed limit sign** shall be located at the beginning of the section of the road or area covered by a speed restriction, with numerals indicating the speed limit in kilometre per hour. The speed limit should be marked in multiples of 5 kmph.
- **Warning sign** for village roads should normally be located at 40m in plain or rolling terrain and 30m in hilly terrain.
- **Curve signs** should be located wherever the direction of alignment changes when the curve radius is less than 90m for Plain or Rolling Terrain and 23m for Hilly Terrain.
- **Rumble strip sign** should be posted 50-60m in advance of the rumble strips provided on the road to control the speed.
- **Barrier sign** should be erected in advance of a gate controlling entry into a road."SLOW BARRIER AHEAD" installed at a distance of 200m from the barrier and "DEAD SLOW BARRIER AHEAD" installed at a distance of 50-100m in plain and rolling terrain and 30-60m in hilly terrain.In case of toll barriers, the words "BARRIER AHEAD" may be replaced by "TOLL BARRIER AHEAD".

- **Unguarded Railway Crossing** located at 200m away from the crossing and a second sign may be erected 50-100m from the crossing in plain and rolling terrain and 30-60m in hilly terrain.
- **Guarded Railway Crossing** located at 200m away from the crossing and a second sign may be erected 50-100m from the crossing in plain and rolling terrain and 30-60m in hilly terrain.
- **Speed Breaker sign** should be posted 50-60m in advance of the speed breaker location.
- **Traffic Signal sign** may be posted 50-100m in advance of the location of traffic signals.
- **Runway sign** may be posted 50-100m in advance of the location of Runway.
- **Series of Bends sign** may be posted 50-100m ahead of the section under question. The sign may be repeated at appropriate intervals if the zig-zag road is very long.

STOP AND GIVE WAY SIGNS



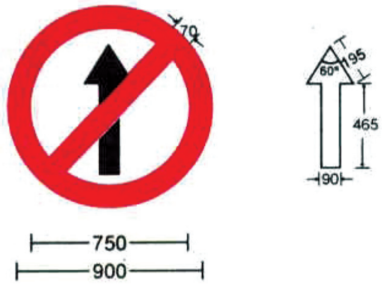
STOP SIGN



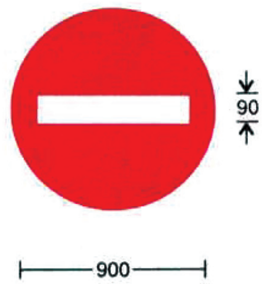
GIVE WAY SIGN

1. Dimensions shown are for normal sized signs
2. All dimensions are in millimetres

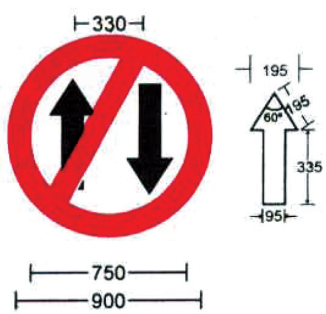
PROHIBITORY SIGNS



STRAIGHT PROHIBITED
OR NO ENTRY



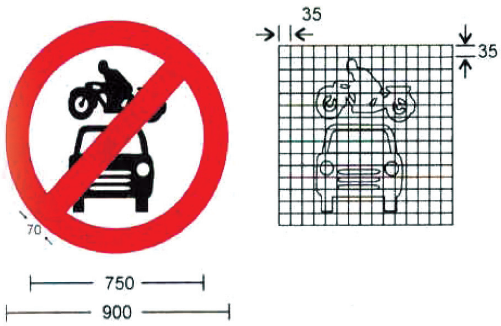
NO ENTRY



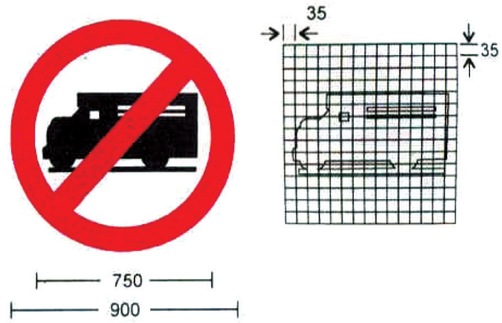
ONE WAY SIGNS

VEHICLES PROHIBITED
IN BOTH DIRECTIONS

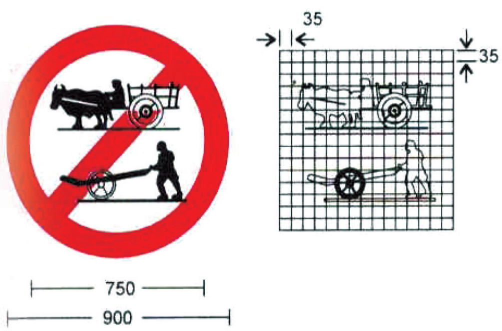
1. Dimensions shown are for normal sized signs
2. All dimensions are in millimetres



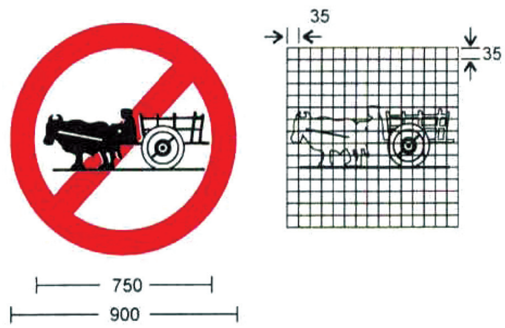
ALL MOTOR VEHICLES PROHIBITED



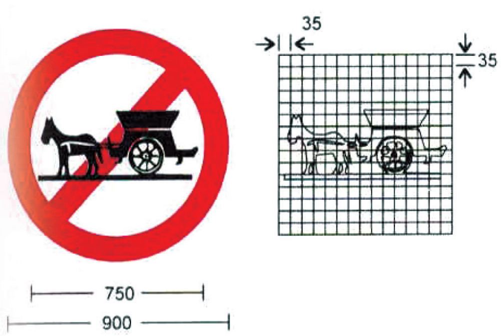
TRUCK PROHIBITED



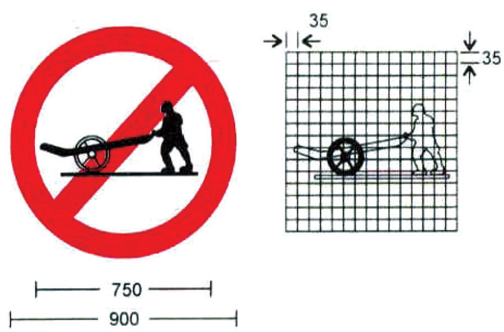
BULLOCK CART & HAND CART PROHIBITED



BULLOCK CART PROHIBITED

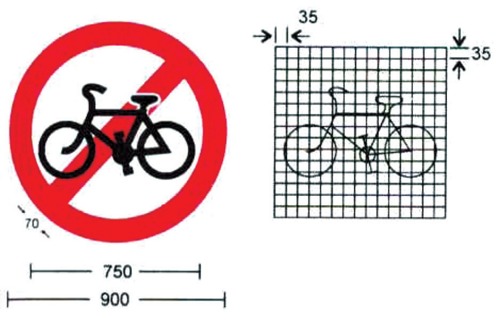


TONGA PROHIBITED

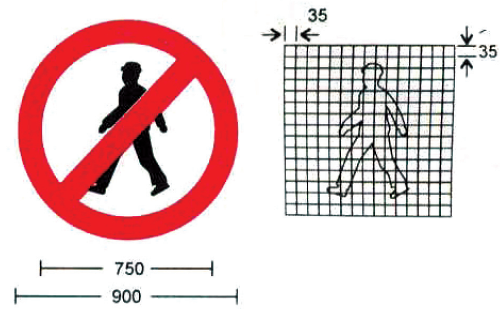


HAND CART PROHIBITED

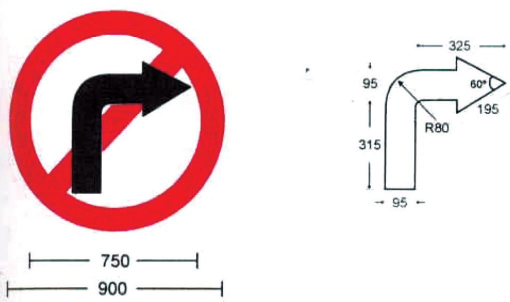
1. Dimensions shown are for normal sized signs
2. All dimensions are in millimetres



CYCLE PROHIBITED

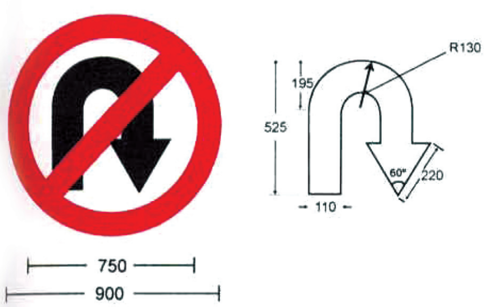


PEDESTRIAN PROHIBITED

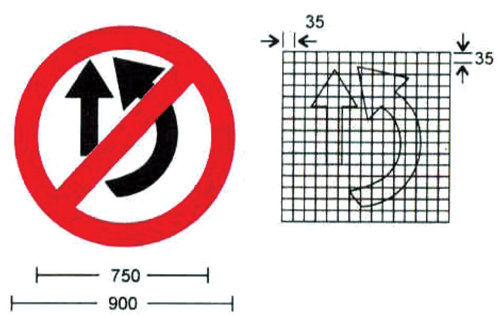


RIGHT TURN PROHIBITED

LEFT TURN PROHIBITED

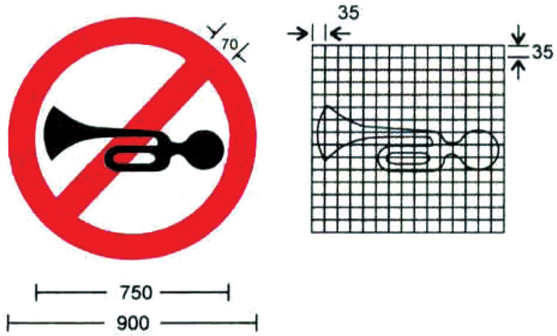


U-TURN PROHIBITED



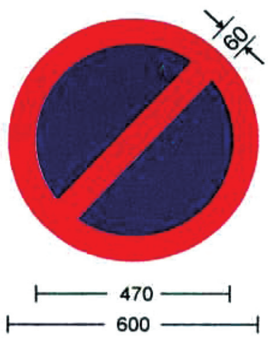
OVERTAKING PROHIBITED

1. Dimensions shown are for normal sized signs
2. All dimensions are in millimetres



HORN PROHIBITED

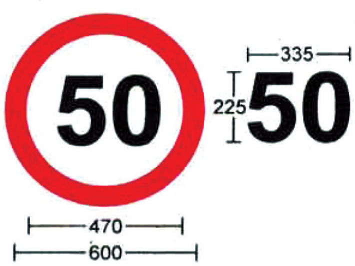
NO PARKING AND NO STOPPING SIGNS



NO PARKING

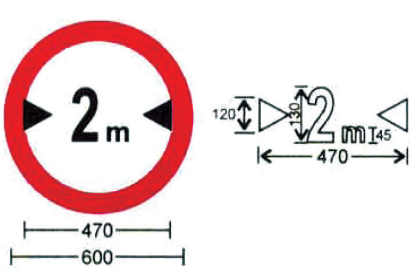
NO STOPPING OR STANDING

SPEED LIMIT AND VEHICLE CONTROL SIGNS

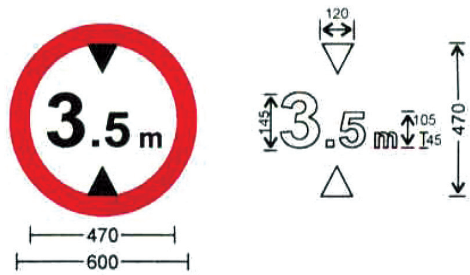


SPEED LIMIT

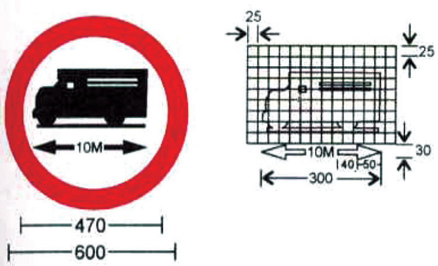
1. Dimensions shown are for normal sized signs
2. All dimensions are in millimetres
3. A definition plate may be attached with the No Parking and No Stopping signs carrying the message in English and other languages as necessary, as also any additional information such as the period during which the restrictions will be in force or the particular vehicles to which it applies.
4. Speed limits for different classes of vehicles may be indicated in separate definition plate attached to the Speed Limit sign.



WIDTH LIMIT

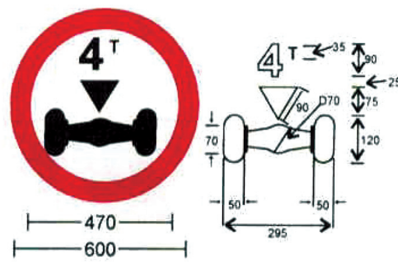


HEIGHT LIMIT



LENGTH LIMIT

LOAD LIMIT

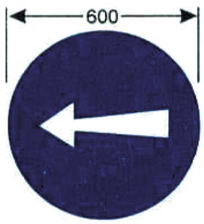


AXLE LOAD LIMIT

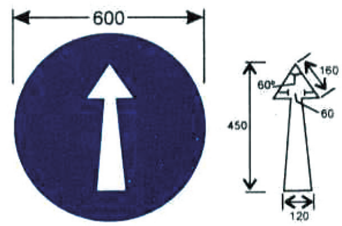
RESTRICTION ENDS SIGNS

1. Dimensions shown are for normal sized signs
2. All dimensions are in millimetres

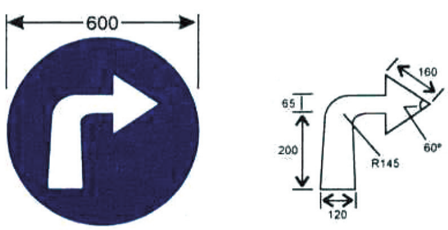
COMPULSORY DIRECTION CONTROL AND OTHER SIGNS



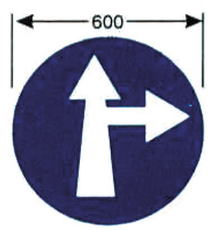
COMPULSORY TURN LEFT
(FOR TURN RIGHT, SYMBOL TO BE REVERSED)



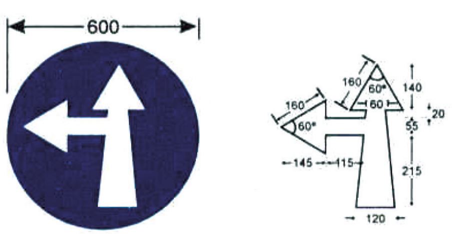
COMPULSORY AHEAD ONLY



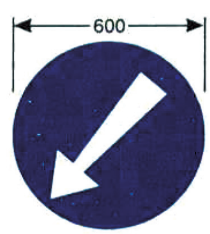
COMPULSORY TURN RIGHT AHEAD
(FOR TURN LEFT, SYMBOL TO BE REVERSED)



COMPULSORY AHEAD OR TURN RIGHT



COMPULSORY AHEAD OR TURN LEFT



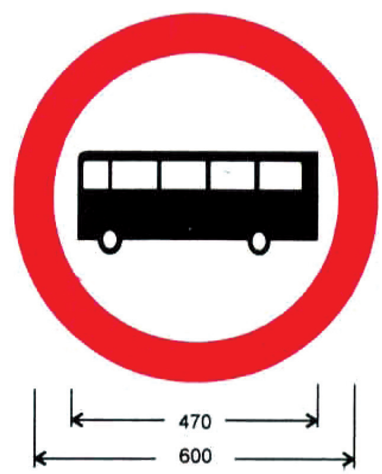
COMPULSORY KEEP LEFT

1. Dimensions shown are for normal sized signs
2. All dimensions are in millimetres

COMPULSORY CYCLE TRACK

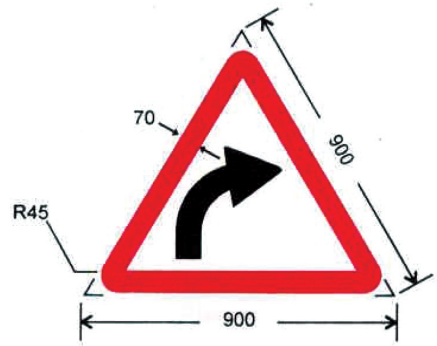
COMPULSORY SOUND HORN

PEDESTRIANS ONLY

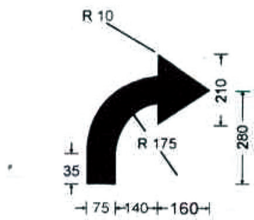


BUSES ONLY

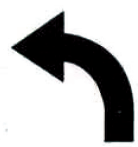
1. Dimensions shown are for normal sized signs
2. All dimensions are in millimetres



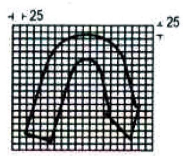
TYPICAL CAUTIONARY SIGN



RIGHT HAND CURVE



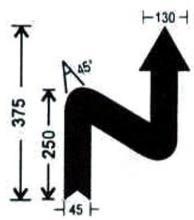
LEFT HAND CURVE



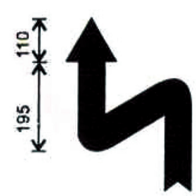
RIGHT

LEFT

HAIR PIN BEND



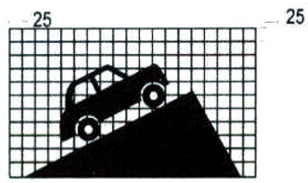
RIGHT



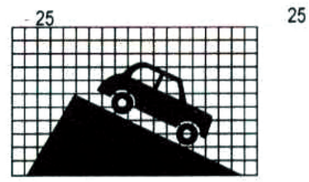
LEFT

REVERSE BEND

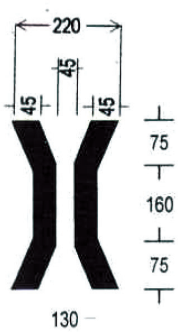
1. Dimensions shown are for normal sized signs
2. All dimensions are in millimetres



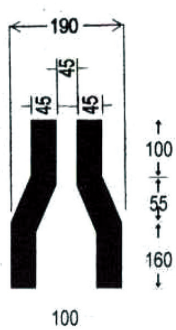
STEEP ASCENT



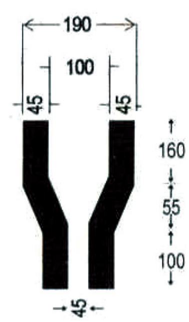
STEEP DESCENT



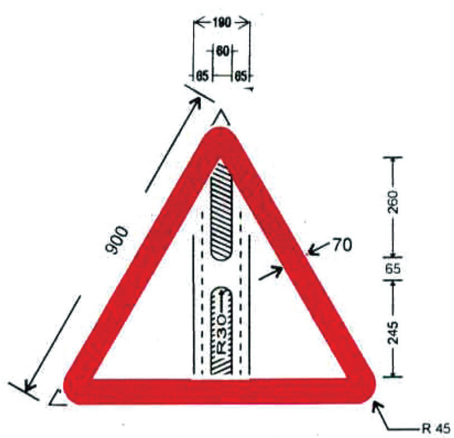
NARROW BRIDGE



NARROW ROAD

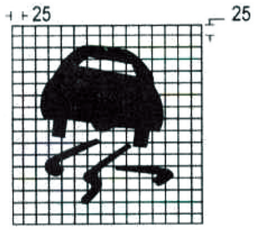


ROAD WIDENS

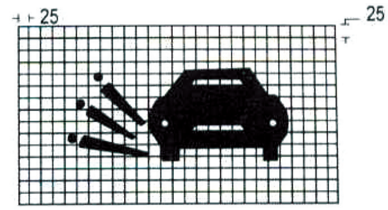


GAP IN MEDIAN

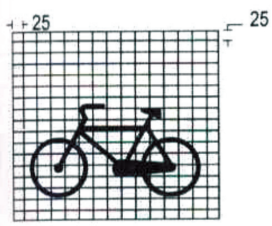
1. Dimensions shown are for normal sized signs
2. All dimensions are in millimetres



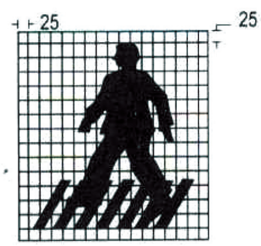
SLIPPERY ROAD



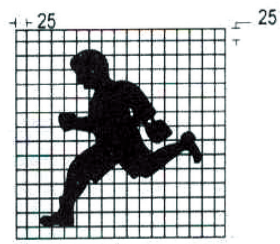
LOOSE GRAVEL



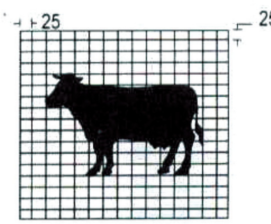
CYCLE CROSSING



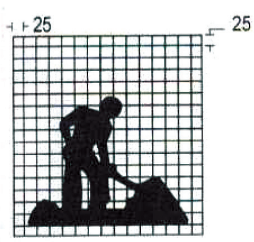
PEDESTRIAN CROSSING



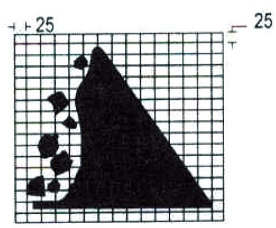
SCHOOL



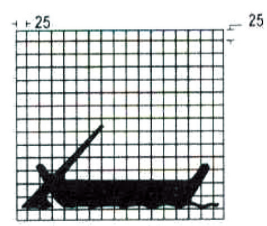
CATTLE



MEN AT WORK

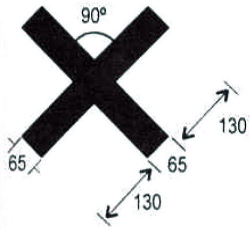


FALLING ROCKS

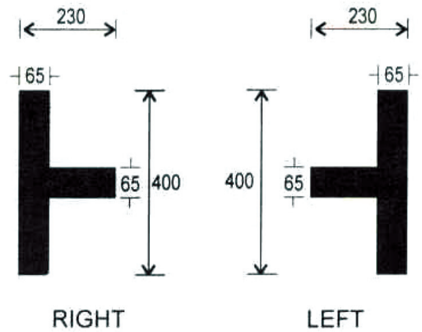


FERRY

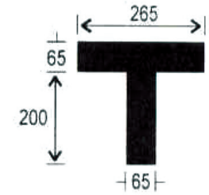
1. Dimensions shown are for normal sized signs
2. All dimensions are in millimetres



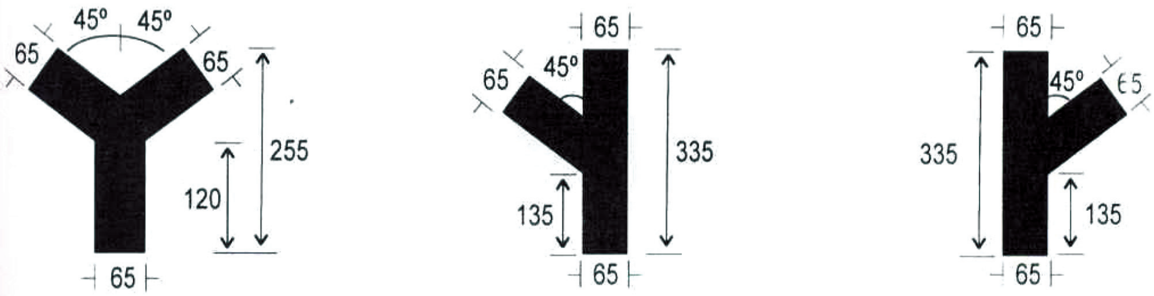
CROSS ROAD



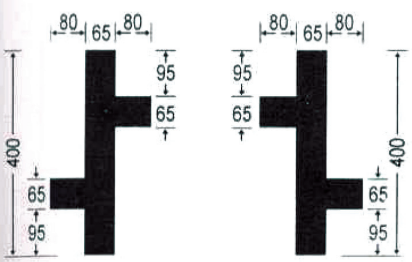
SIDE ROAD



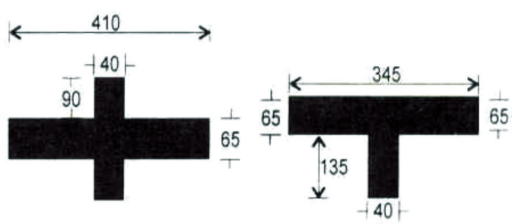
T-INTER-SECTION



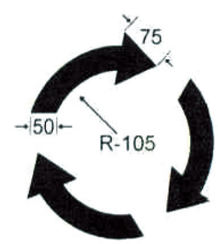
Y-INTER-SECTION



STAGGERED INTER-SECTIONS

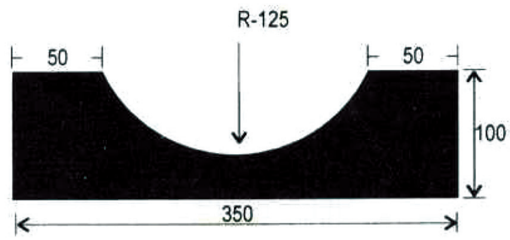


MAJOR ROAD

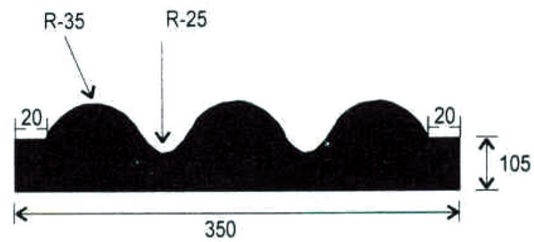


ROUND ABOUT

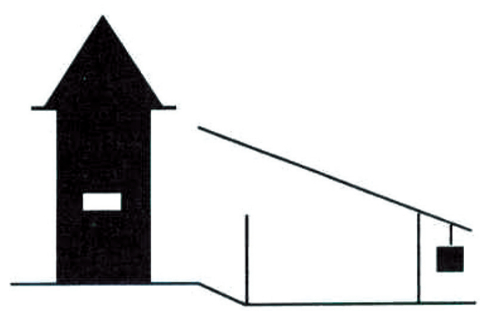
1. Dimensions shown are for normal sized signs
2. All dimensions are in millimetres



DANGEROUS DIP

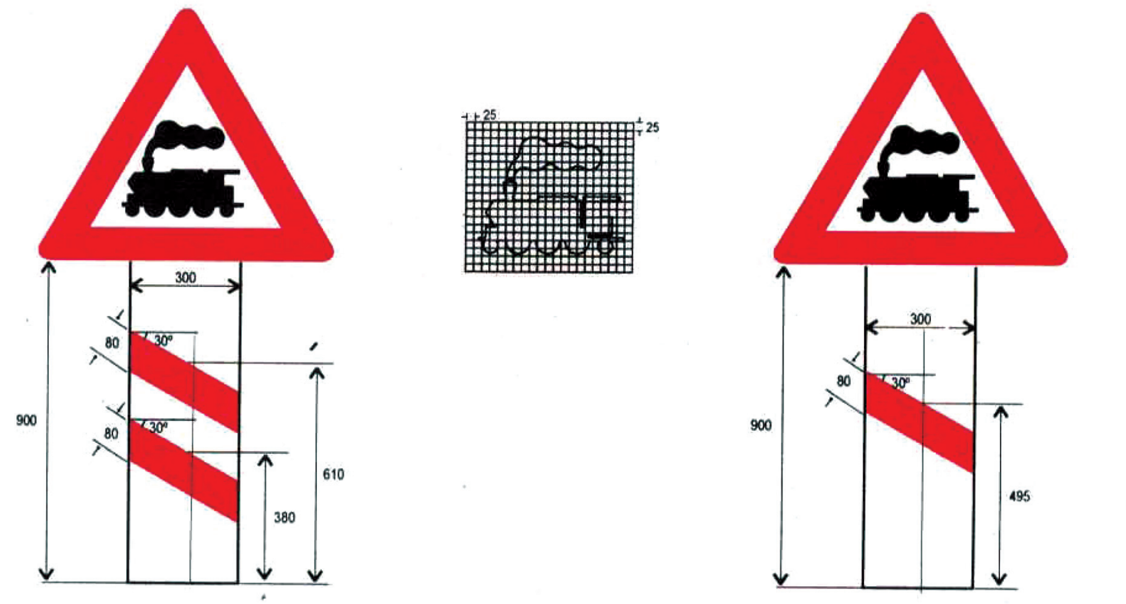


RUMBLE STRIP



BARRIER
(A DEFINITION PLATE MAY BE ATTACHED WITH THE SIGN INDICATING THE DISTANCE TO THE BARRIER AND ANY OTHER INSTRUCTIONS)

1. Dimensions shown are for normal sized signs
2. All dimensions are in millimetres

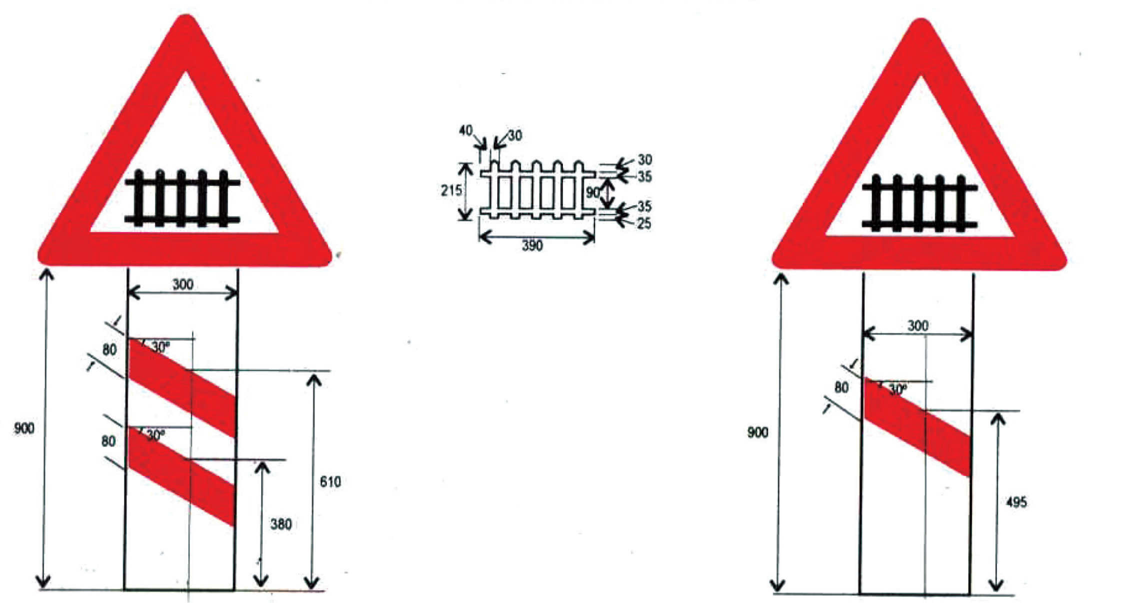


200 METRES

50-100 METRES IN PLAIN & ROLLING TERRAIN AND 30-60 METRES IN HILLY TERRAIN

UNGUARDED RAILWAY CROSSING

(FOR EACH CROSSING, BOTH SIGNS ARE TO BE USED AT DISTANCES INDICATED ABOVE)



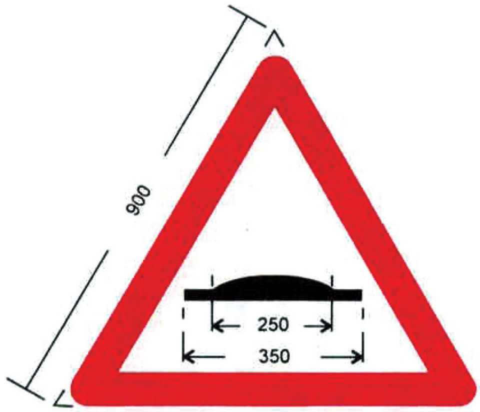
200 METRES

50-100 METRES IN PLAIN & ROLLING TERRAIN AND 30-60 METRES IN HILLY TERRAIN

GUARDED RAILWAY CROSSING

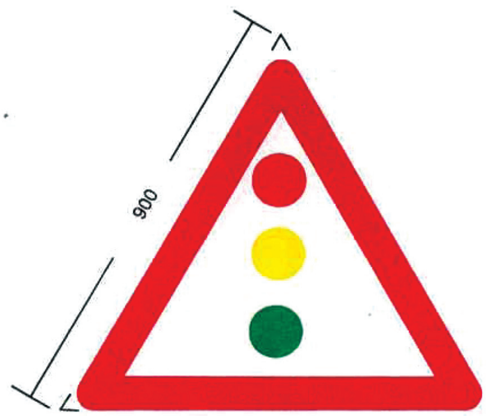
(FOR EACH CROSSING, BOTH SIGNS ARE TO BE USED AT DISTANCES INDICATED ABOVE)

1. Dimensions shown are for normal sized signs
2. All dimensions are in millimetres

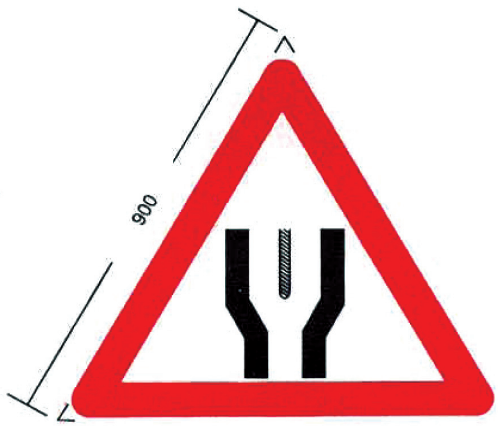


SPEED BREAKER

END OF DUAL CARRIAGEWAY



TRAFFIC SIGNAL



START OF DUAL CARRIAGEWAY

RUN-WAY

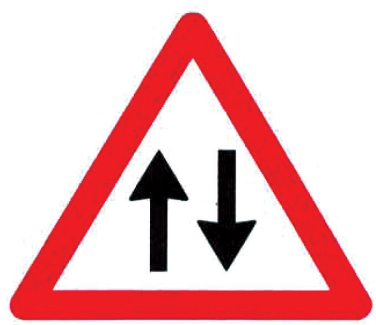
SERIES OF BENDS

1. Dimensions shown are for normal sized signs
2. All dimensions are in millimetres

DIVERSION TO THE OTHER CARRIAGEWAY OF DUAL CARRIAGEWAY ROAD

OVERHEAD CABLE

QUAYSIDE OR RIVER BANK



TWO-WAY TRAFFIC

LANE CLOSED (TWO LANE ROAD)

SUDDEN SIDE WINDS

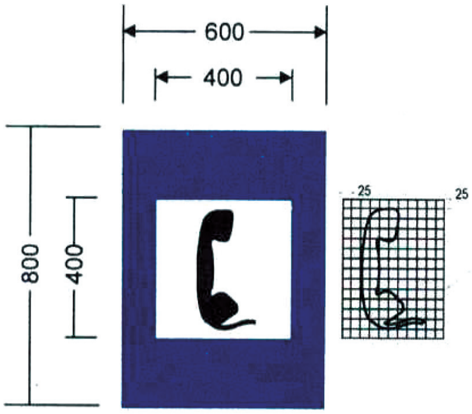
LANE CLOSED (THREE LANE ROAD)

REDUCED CARRIAGEWAY

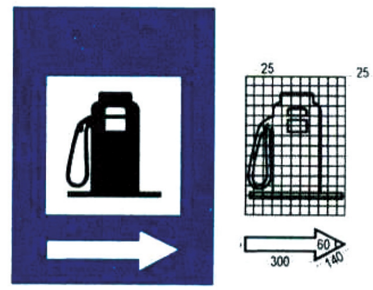
LANE CLOSED (FOUR LANE ROAD)

ROUGH ROAD

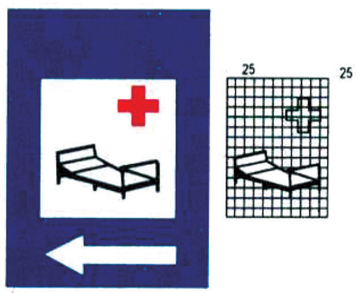
FACILITY INFORMATION SIGNS



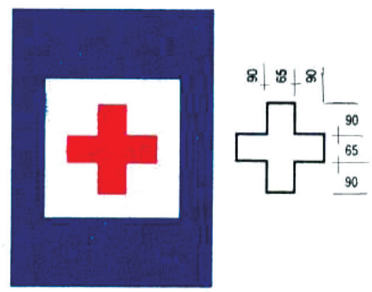
PUBLIC TELEPHONE



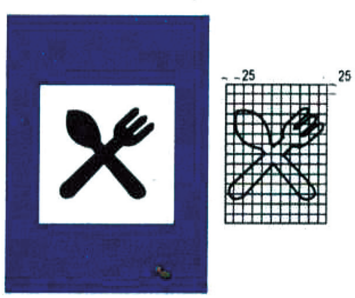
FILLING STATION



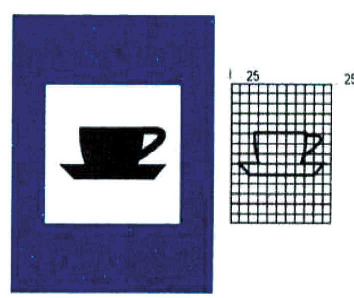
HOSPITAL



FIRST-AID POST



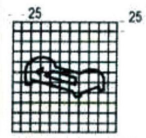
EATING PLACE



LIGHT REFRESHMENT

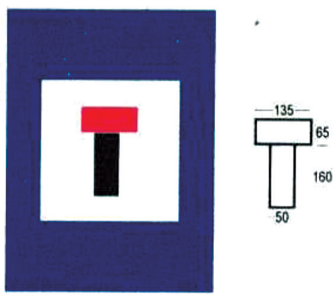
1. Dimensions shown are for normal sized signs
2. All dimensions are in millimetres

OTHER USEFUL INFORMATION SIGNS

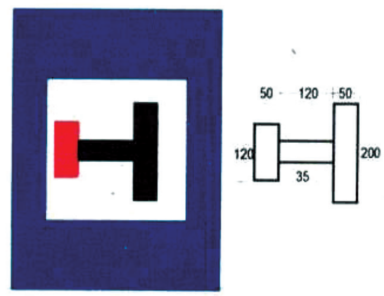


(A DEFINITION PLATE SHOULD BE ATTACHED INDICATING WHETHER THE PLACE IS REST HOUSE, HOTEL OR MOTEL)

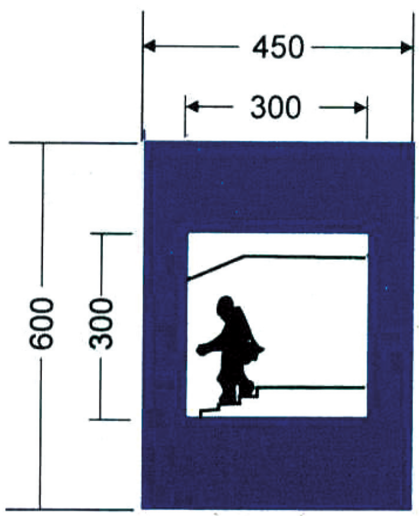
RESTING PLACE



NO THROUGH ROAD



NO THROUGH SIDE ROAD



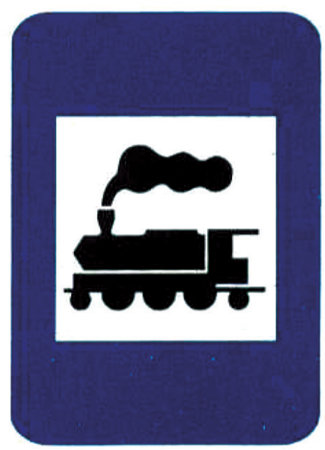
PEDESTRIAN SUBWAY

1. Dimensions shown are for normal sized signs
2. All dimensions are in millimetres

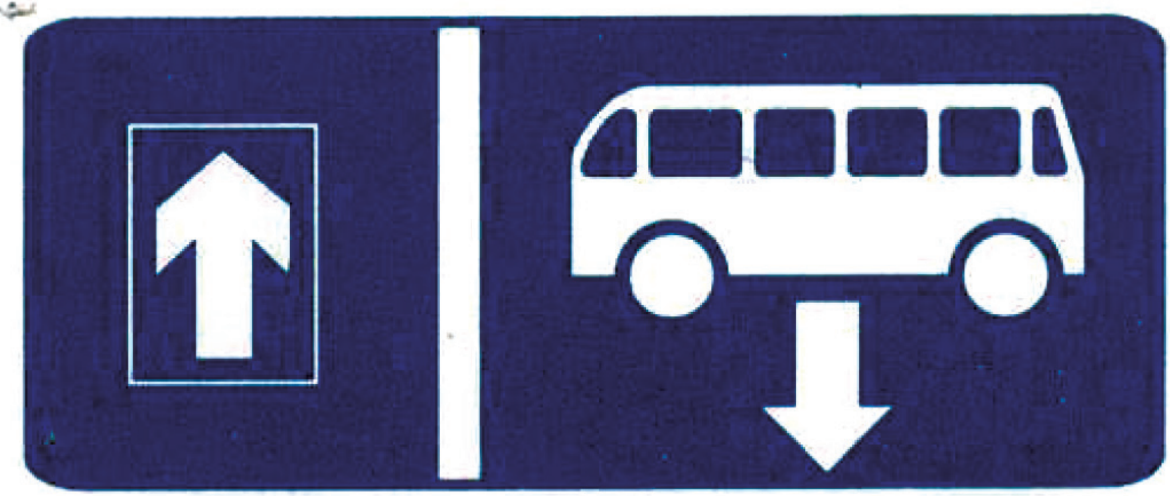
AIRPORT

REPAIR FACILITY

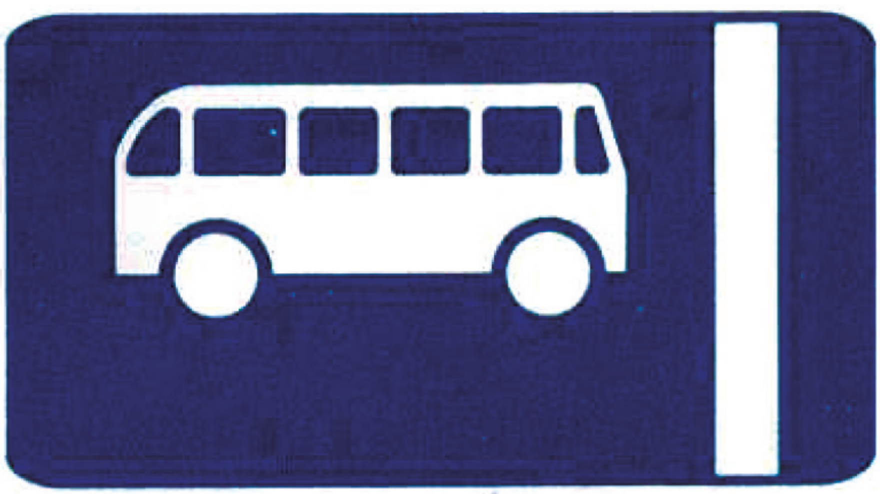
POLICE STATION



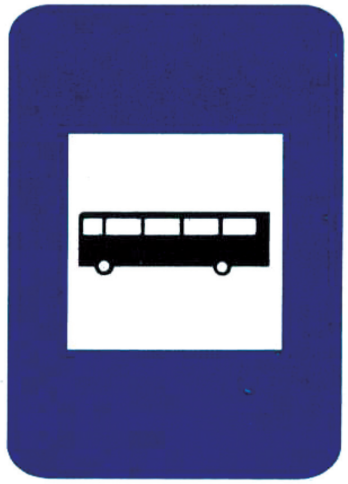
RAILWAY STATION



(a) CONTRA-FLOW BUS LANE



(b) BUS LANE



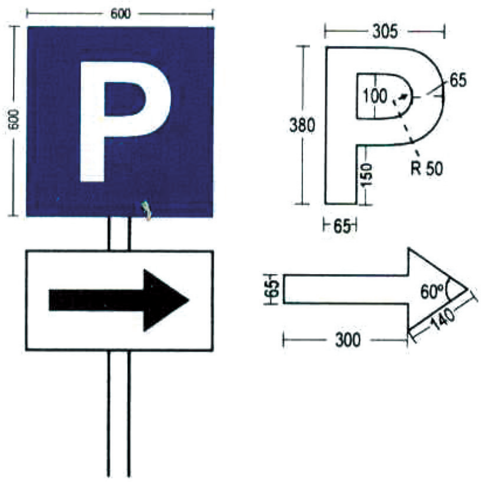
BUS STOP

TAXI STAND

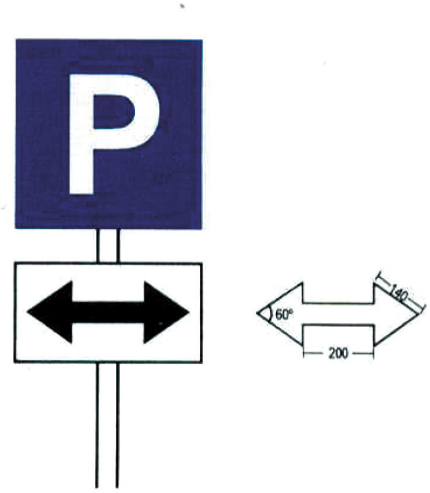
AUTO-RICKSHAW STAND

CYCLE-RICKSHAW STAND

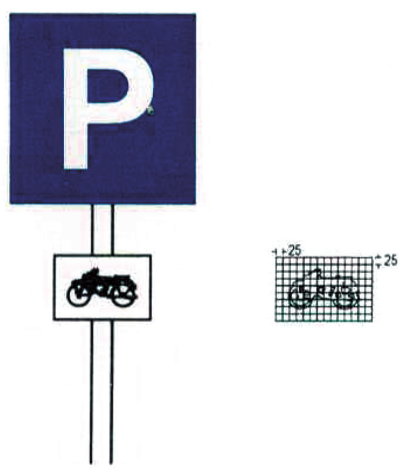
PARKING SIGNS



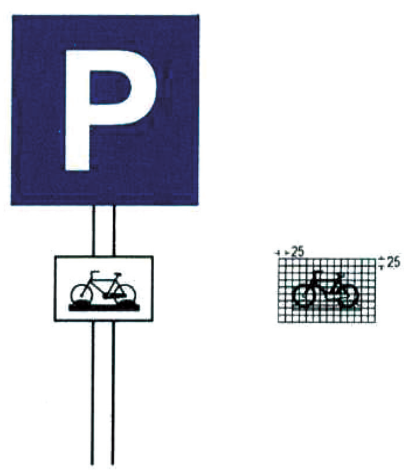
PARKING THIS SIDE



PARKING BOTH SIDES

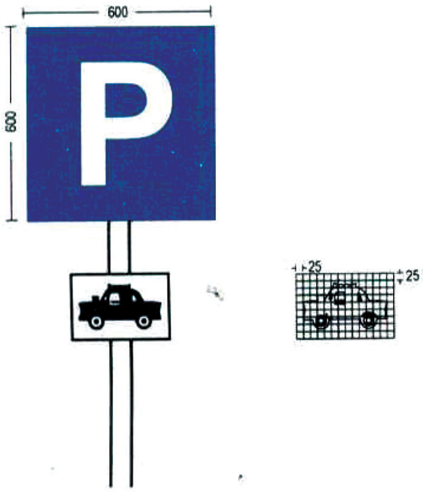


SCOOTER & MOTOR CYCLE STAND

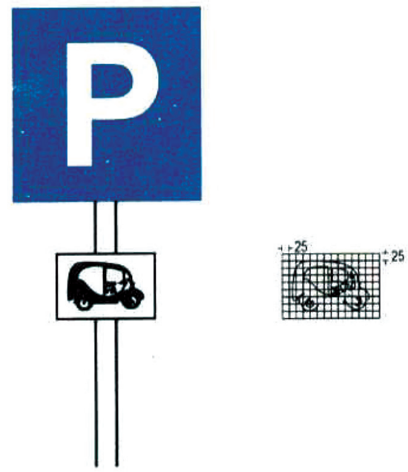


CYCLE STAND

1. Dimensions shown are for normal sized signs
2. All dimensions are in millimetres



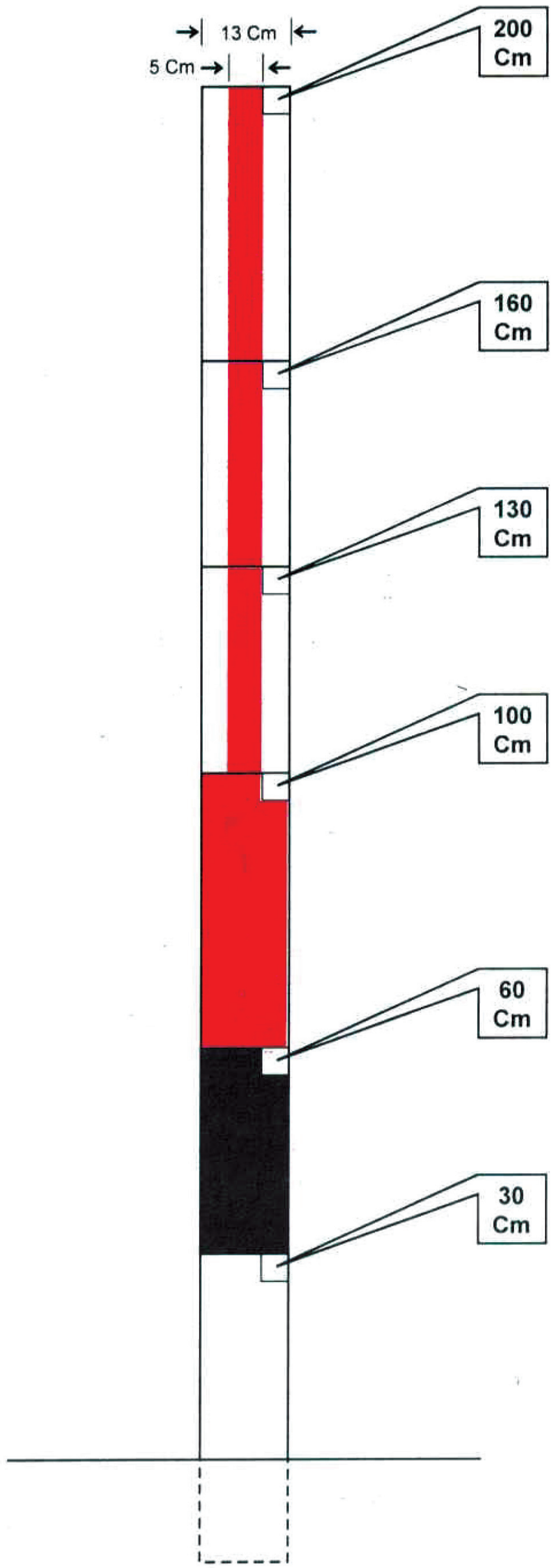
TAXI STAND



AUTO-RICKSHAW
STAND

CYCLE-RICKSHAW
STAND

1. Dimensions shown are for normal sized signs
2. All dimensions are in millimetres



FLOOD GAUGE

PREPARATION OF
DETAILED PROJECT REPORT

13. Preparation of DPR

13.1. INTRODUCTION

Detailed Project Report (DPR) should be based on detailed survey and investigations, design and technology choice and should be of such detail that the quantities and costs are accurate, and no cost over-run takes place due to changes in scope of work or quantities at the time or execution. Guidance may be taken from IRC: SP: 19 for preparing the DPR.

The Engineers should fully understand the need for appropriate Designs with respect to Geometrics, Pavement Crust, Surface Drainage, CD Works as well as the measures for Environmental Conservation. The steps involved in the preparation of a DPR are as under:

1.	Selection of alignment - Transect walk
2.	Topographical survey
3.	Soil survey
4.	Material survey
5.	Hydrological survey
6.	Traffic Estimation
7.	Pavement Design
8.	Drainage Plan
9.	Design of cross-drainage works
10.	Preparation of Land Plans
11.	Preparation of road drawings
12.	Preparation of drawings of C.D works
13.	Selection of specifications
14.	Estimation of quantities of items of work
15.	Analysis of Rates
16.	Estimate
17.	Preparation of DPR documents

13.2. GUIDELINES FOR THE PREPARATION OF DETAILED PROJECT REPORT

1. Engineering drawings from surveys such as LS and CS drawn to scale as per IRC SP: 19 and the details of the processed data of LS and CS and the computation of quantities.

2. Sub-grade soil particulars like soaked CBR value, OMC, density etc from an approved technical institution/laboratory. The wet sieve analysis of the tested soil and its HRB classification should be furnished along with the CBR test results. The soil for the CBR test in case of upgradation of existing pavements should be taken by cutting open the existing pavement-shoulder edge below the existing base course. It is essential that the one CBR value for each kilometer of the proposed roads is made available for the design of pavement.

3. Traffic volume count and the processed data as per IRC SP: 19 and the growth factors should be furnished in the DPR. The growth factor adopted should be justified. The method adopted for the traffic projection should be presented in the report.

4. Detailed pavement design is to be furnished in the DPR. Drainage layer needs to be provided for raising the embankment in case of new pavement construction in black cotton soil sub grades. The granular sub-base and/or the drainage layer should extend for the full formation width. The cost for the granular sub-base should be worked out based on a realistic design by mechanical stabilization of two or more materials and shown in the rate analysis.

5. Many of the proposals are made with only conventional construction methods irrespective of the suitable low- cost materials within reasonable reaches. Attempts seldom are made to adopt soil stabilization and use of locally available materials with proper treatment which result in the reduction of cost of construction of the road. The engineers should attempt to adopt new and innovative technologies and use locally available materials for minimizing the cost of construction.

6. Geometric design for the project road viz., Camber, Super-elevation, design of the horizontal and vertical curves, extra widening at curves, design gradient etc., as per the Rural Roads Manual should be furnished in the report.

7. If the existing old /worn out WBM surfaced pavement is to be upgraded as a black top surface, the CBR of the soil from below the existing road is to be tested and the thickness of the pavement designated as per the projected traffic. The existing thickness of the pavement is to be deducted to compute the balance of the thickness and the type of the additional layers to be constructed. Provision should be made in the estimate for the profile correction to the desired camber and the quantity of material required for the profile correction should be substantiated with adequate number of cross-section drawing and levels.

8. If the existing pavements is a single layer of WBM and is in a very bad or worst condition, the following measures are suggested. (1) Rise the road level considering the local conditions like wet fields on either side etc., after scarifying the worn out layer of WBM,(2) A layer of GSB be constructed as per the Rural Roads Manual,(3) The WBM aggregates removed for the rehabilitation are used in the new WBM layer,(4) The scarified metal should be suitably accounted.

9. Hydraulic studies and the computation of the linear waterway and the design of the CDs as well as the design of the side drains should be furnished in the DPR.

10. Wherever there are fields/farm lands on either side, the existing cart-tracks are to be provided with NP2 pipes of 45cm diameter with adequate thickness of soil/sand cushion, so that the drains are not closed by farmers subsequently for access.

11. Provision of the Scheme logo, Km and HM stones, guard stones and sign boards and other furniture are to be made as per Rural Roads Manual.

12. A certificate to the following effect needs to be furnished

    (i) Required formation width is available as per the Rural Roads Manual.

    (ii) Proposed road work forms part of the Register of Roads

    (iii) All the details furnished in the DPR are true and the concerned engineers are responsible for the accuracy of all the information furnished in the DPR.

13.3. ROAD ALIGNMENT AND SURVEYS

The location or the layout of the centre line of the road on the ground is called the alignment. The horizontal alignment includes the straight path, the horizontal deviations and curves. Changes in gradient and vertical curves are covered under vertical alignment of road. The alignment of rural road should be decided only after conducting proper surveys and investigations. In general, most new roads will also have to follow the existing cart tracks and other such existing alignments. However, during route location the following points should be considered.

1. Adoption of appropriate geometric design standards and safety requirements
2. Keeping to the high ground so as to avoid low lying areas and minimising the drainage requirements
3. Following the land contours as far as practicable to reduce the extent of cut and fill
4. Conforming to any property boundaries to the extent possible
5. Avoiding or minimising the effect on vegetation
6. As far as possible, alignment should not interfere at any stage with services, like power transmission lines, water supply mains, etc.
7. A new road should be aligned very carefully, as improper alignment would mean either capital loss initially in construction as well as recurring loss in cost of maintenance and vehicle operation. Once the road is aligned and constructed, it is not easy to change the alignment due to increase in cost of adjoining land and construction of costly structures by the roadside.

The ideal alignment between two points should satisfy the following aspects:

- Short alignment
- Easy to construct and maintain
- Safe enough for construction and maintenance
- Economical

- Sound alignment
- Aesthetics of the area
- Environmental protection

13.4. GOVERNING FACTORS FOR ROUTE SELECTION

13.4.1. General Considerations

(i) The alignment should be as direct as possible so that there is maximum economy in cost of construction, maintenance and transportation.

(ii) The grades, curvatures and profiles should be as designed as to be economical, consistent with the service requirements.

(iii) While improving the existing alignment, the endeavor should be to utilize the existing facility as much as possible in order to minimize the cost and effort of land acquisition and construction.

(iv) The alignment should not interfere at nay stage with services, like power transmission lines, water supply mains, etc.

(v) Embankment and pavement account for major proportion of the road cost; therefore, availability of material for embankment and pavement construction should be kept in view while finalising the alignment. Similarly, good subgrade conditions would mean lower pavement cost and thus the subgrade conditions also effect the choice of alignment. To the extent possible, areas susceptible to subsidence (due to mining, etc), marshy and low lying areas prone to flooding, inundation and erosion should also be avoided.

(vi) While connecting population centers, the alignment should preferably skirt round the population pockets rather than pass through congested areas.

13.5. FACTORS AFFECTING ALIGNMENT The various factors, which control the road alignment, may be listed as:

(a) Obligatory points

(b) Traffic

(c) Economics

(d) Drainage

(e) Other considerations

13.5.1. Obligatory Points

There are control points governing the alignment of the roads. These control points may be divided broadly into two categories:

(a) Points through which the alignment is to pass

(b) Points which the alignment should avoid.

Obligatory points through which the road alignment has to pass may cause the alignment to often deviate from the shortest path.

The various examples of this category may be a bridge site, an intermediate town, a mountainous pass or a quarry, pond etc. When it is necessary to cross Hill Mountains or high ridges, the various alternatives are to cut a tunnel or to go round the hills or to deviate until a suitable hill pass is available.

13.5.2. Traffic

In most of the cases, the people use certain routes traditionally. These may either be due to convenience, social connection with other areas, etc. The proposed alignment should keep in this view this traffic flow pattern. At the same time one should also have a fair judgement of future trends in mind.

13.5.3. Geometric Designs

Geometric design factors such as, gradient, radius of curve and sight distance would also govern the final alignment of the road it should be finalized in such a way that the obstructions to visibility do not cause restrictions to the sight distance requirements.

13.5.4. Economy

The alignment finalized based on the above factors should also be economical. Care should be taken to see that it is not likely to involve costly maintenance and operational expenses.

13.5.5. Other Considerations

Various factors govern the alignment are drainage, hydrological factors, social obligations, etc. the sub-surface water level, seepage flow and high flood level are also the factors to be kept in view.

13.5.6. SPECIAL CONSIDERATIONS FOR HILL ROADS

In hill roads, additional care has to be taken for ecological considerations, such as:

1. Stability against geological disturbances
2. Land degradation and soil erosion
3. Destruction and denudation of forest
4. Interruption an disturbance to drainage system
5. Aesthetic considerations
6. Siltation of water resources.

13.5.7. SPECIAL CONSIDERATION IN SAND DUNE AREAS

The road should be located in such a way that it causes minimum interference to the flow of sand –laden winds. Therefore, the roadway should merge with the line of the land as much as possible. Location along the face of the dunes should be avoided. Locations where sand is loose and unstable should be avoided.

13.6. SURVEYS

Final location of the alignment is based on ground verification, and therefore the following engineering surveys are to be carried out in addition to traffic surveys.

1. Reconnaissance
2. Preliminary survey
3. Determination of final centre line
4. Final location and detailed survey

To facilitate the survey it will be advisable to make use of modern techniques like aerial survey, photogrammetry and remote sensing.

13.6.1. Traffic Surveys And Analysis

Information about traffic is indispensable for any road project since it would form the basis for the design of the pavement, fixing the number of traffic lanes, design of intersections and economic appraisal of the project, etc.

Classified Traffic Volume Count

Count of traffic is the basic traffic study required in connection with many types of highway projects. A system of traffic census is in vogue in the country under which 7 day traffic counts are taken once or twice a year. When traffic census data from existing count stations are compiled, it may be found useful to collect past data (preferably about 10 years) so as to establish meaningful past growth trends for each vehicle class).

13.6.2 . Reconnaissance Survey

The main objective of reconnaissance survey is to examine the general character of the area for the purpose of determining the most feasible route onroutes, for further more detailed investigations. Data collected should be adequate to examine the feasibility of all the different routes in question, as also to furnish the Engineer-in-Charge with approximate estimates of quantities and costs, so as to enable him to decide on the most suitable alternative or alternatives. The survey should also help in determining any deviations necessary in the basic geometric standards to be adopted for the highway facility.

13.6.3. Preliminary Survey

The preliminary survey is a relatively large scale instrument survey conducted for the purpose of collecting all the physical information which affects the proposed location of a new highway or improvements to an existing highway. In the case of new roads, it consists of running an accurate traverse line along the route previously selected on the basis of the reconnaissance survey.

In the case of existing roads where only improvements are proposed, the survey line is run along the existing alignment. During this phase of the survey, topographic features and other features like houses, monuments, places of worship, cremation or burial grounds, utility lines, existing road and railway lines, stream river, canal crossings, are taken and bench marks established.

The data collected at this stage will form the basis for the determination of the final centre line of the road. For this reason, it is essential that every precaution should be taken to maintain a high degree of accuracy. Besides the above, general information which may be useful in fixing design features within close limits is collected during this phase. The information may concern traffic, soil, construction materials, drainage etc. and may be collected from existing records as through intelligent inspection/ simple measurements. It may be found convenient to divide the road into homogeneous section from traffic consideration and prepare a typical estimate for one km stretch as representative of each homogeneous section. With the data collected, it should be possible to prepare rough cost estimates within reasonably close limits for obtaining administrative approval, if not already accorded and for planning further detailed survey and investigations. In particular, information may be collected regarding:

i) The highest sub-soil and flood water levels, the variation between the maximum and minimum and the nature and extent of inundation, if any gathered from local enquiries or other records. These should be correlated to data about the maximum and minimum rainfall and its duration and spacing, etc., by appropriate hydrological analysis.

ii) The character of embanknment foundations including the presence of any unstable strata likes micaceous schists, poor drainage or marshy areas etc. This is particularly necessary in areas having deep cuts to achieve the grade.

iii) Any particular construction problem of the area like, sub-terrean flow, high level water storage resulting in steep hydraulic gradient across the alignment canal crossings and their closure periods. Information regarding earlier failures in the area of slides or settlements of slopes, embankments and foundation, together with causes thereto may also be gathered from records and enquiry where feasible.

iv) In cut sections, the nature of rock i.e., hard, soft etc., should be determined by trial pits or boreholes. This is essential to make realistic cost estimates.

13.6.4. Determination of Final Centre Line

Making use of the maps from preliminary survey showing the longitudinal profile, cross-sections and contours, a few alternative alignments for the final centerline of the road are drawn and studied and the best one satisfying the engineering, aesthetic and economic requirements is selected.

13.6.5. Final Location and Detailed Survey

The alignment finalized after the preliminary survey is to be translated on the ground by establishing the centerline. The line to be established in the field should follow as closely as practicable the line finalized after the preliminary survey and confirming to the major and minor control points established and the geometric design standards. The data collected during detailed survey should be elaborate and complete for preparing detailed plans and estimate of the project.

13.6.6. Survey Procedure

Physical features, such as, buildings, monuments, burial grounds, cremation grounds, places of worship, posts, pipelines, existing roads and railway lines, stream/ river/ canal crossings, cross-drainage structures etc., that are likely to affect the project proposals should be located by means of offsets measured from the traverse line. Where the survey is for improving or upgrading an existing road, measurements should also be made for existing carriageway, roadway and location and radii of horizontal curves. In case of highways in rolling and hilly terrain the nature and extent of grades, ridges and valleys and vertical curves should necessarily be covered. The width of land to be surveyed will depend on the category of road, purpose of the project, terrain and other related factors. Generally, the surveys should cover the entire right-of-way of the road, with adequate allowance for possible shifting of the center line from the traverse line. Levelling work during a preliminary survey is usually kept to the minimum. Generally, fly levels are taken along the traverse line at 50 metre line intervals and at all intermediate breaks in ground. To draw contours of the strip of land surveyed, cross-sections should be taken at suitable intervals, generally 100 to 250 m in plain terrain, upto 50 m in rolling terrain, and upto 20 m in hilly terrain. To facilitate the levelling work, bench marks, either temporary or permanent, should be established at intervals of 250 to 500 metres. The levels should be connected to GTS datum.

13.6.7. Map Preparation

Plans and longitudinal sections (tied to an accurate base line) prepared as a sequel to the preliminary survey are referred to for detailed study to determine the final center line of the road. At critical locations, like sharp curves, hair-pin bends, bridge crossings, etc., the plan should also show contours at 1-3 metre intervals, particularly for roads in rolling or hilly terrain so as to facilitate the final decision. Scales for the maps should generally be the same as adopted for the final drawings.

The following scales are suggested:

i) Built-up areas and stretches in hilly terrain 1:1000 for horizontal scale and 1:100 for vertical scale.

ii) Plain and rolling terrain 1:2500 for horizontal scale and 1:250 for vertical scale.

For study of difficult locations, such as, steep terrain, hair-pin bends, sharp curves, bridge crossings etc., it may be convenient to have plans to a larger scale than recommended above. If necessary, these plans may show contours preferably at 2 m interval, though this could be varied to 1.5 m according to site condition.

13.6.8. Soil and Materials Survey

Investigations for soil and other materials for construction are carried out in respect of the likely sources and the availability and suitability of materials. Some other investigations, for instance in respect of landslide prone locations may also be conducted at this stage. In particular soil and materials surveys are required:

i) to determine the nature and physical characteristics of soil and soil profile for design of embankment and pavement

ii) to determine the salt content in soil in areas known to have problems or where the composition of the design crust requires such testing

iii) to determine the proper method(s) of handling soil.

iv) to classify the earthwork involved into various categories such as rock excavation, earthwork in hard soil etc.

v) to gather general information regarding sub-soil water level and flooding and

vi) to locate sources for aggregates required for pavement and structures and to ascertain their availability and suitability for use

vii) locate source of good quality water suitable for use in different items and work particularly the current work.

13.6.9. Design of Flexible Pavement Design

For new roads, the soil data already collected in earlier phases of the survey should be studied in detail for ascertaining the variability/ homogeneity of the soil profile, and planning further investigations. Where pavement design related to

widening/ strengthening of an existing road, the road should be divided into more or less identical sections on the basis of actual performance and pavement composition, as the basis for further testing. For pavement design, apart from the general soil tests referred to earlier, CBR test should be conducted for soaked, unsoaked or both these conditions depending on the design requirements spelt out in IRC:37. Frequency of CBR testing may be decided based on the soil classification tests conducted at close interval of 500m –1,000m. Overall objective should be to get strength results for all changes in soil type or each demarcated section of similar performance.

13.6.10 Detailed Investigation for Rigid Pavement Design

For design of cement concrete pavement in the case of new construction, K value tests should be carried out with 75 cm diameter plate at the rate of generally, one test per km lane unless foundation changes warrant additional tests.

13.6.11. Drainage Studies

Drainage of road refers to the satisfactory disposal of surplus water within the road limits. The water involved may be rain falling on the road, surface runoff form the adjacent land, seepage water moving through sub-terranean channels, or moisture rising by capillary action. Adequate information about drainage patterns is necessary to devise an effective drainage system, which brings into focus the need for requisite studies and investigations. Drainage studies have the following principal objectives: (i) Fixing the grade line of the road (ii) Design of pavement and (iii) Design of the surface/ sub-surface drainage system

13.6.12. High Flood Level

HFL governs the grade line of a road and its reasonably precise estimation is particularly important. The design HFL should be based on a return period depending upon the importance of the structure. Information in this regard can normally be had from the irrigation department who maintain and analyse such data. Inspection and local enquiry can often provide very useful information, such as marks left on trees or structures indicating the maximum flood level. HFLs so determined should also be compared with those for the adjoining sections of the road or nearby railway/ irrigation embankments to correct any mistake. Construction of a highway embankment may sometime block the natural drainage paths and cause heading up on the water on upstream side. In finalizing the HFL, due allowance for the possible afflux in such circumstances must be made. Adequate number of openings shall be provided.

13.6.13. Depth of Water-Table

Knowledge of the high water-table (for various return periods) is necessary for fixing the subgrade level deciding the thickness of pavement, and taking other design measures such as provision of capillary cut-offs or interceptor drains. Depth of water-table may be measured at open walls along the alignment or at holes specially bored for the purpose. Usually observations should be taken at intervals of one kilometer or less, preferably at the time of withdrawal of the monsoon, when the water-table is likely to be the highest. If there is any evidence of spring flow in the test holes, this should be carefully recorded. The depth of water-table should be measured with reference to a common datum. Besides high water-table it may be helpful to know the fluctuations in water-table. For this purpose, measurements of the lowest water-table in the driest month should also be made. In areas where the climate is arid and the water-table is known to be at least one metres below the general ground level, depth of water table need not be measured.

13.6.14. Ponded Water Level

In situation where water stagnates by the roadside for considerable period, e.g. irrigated fields etc., information about the levels of standing water should also be collected and considered for design in conjunction with HFL and water-table.

13.6.15. Special Investigations for Cut-Sections

In cut sections in rolling or hilly terrain, the problem of seepage flows is common. The seepage water may be due to high water-table, sub-soil water moving through sub-terranean channels where a permeable soil layer overlies an impermeable stratum, or irrigation water in adjoining fields situated at a higher level. Where such conditions exists, it may be necessary to intercept the seepage flow to prevent saturation of the road bed. Preventive measures in this regard can consist of deep side drains of open or French type (to check side-way seepage or lower the water-table), buried transverse drains (to cut-off the longitudinal sub-surface flow, underneath the pavement, especially at the transition from cut to fill sections) or blanket course/ sub-drains below the pavement in combination with side drains (to protect the pavement from excess hydraulic pressure). Actual treatment in each case will depend on factors such as the intensity of seepage, depth of the permeable strata etc., for which investigations would be required.

Analysis of water-table information in conjunction with the surface profile will indicate the possible problematic areas as regards seepage flows. As an adjunct to this, ground within the highway limits should be surveyed soon after the rainy season to visually identify the seepage zones, normally characterized by wet areas and patches. The following detailed investigations could then be taken up at these locations to decide the appropriate drainage measures against seepage:

i) Soil profile of the area i.e., soil type and the depth of the various strata.

ii) The head under which seepage water is flowing and its hydraulic gradient. This could be measured through a series of stand pipes placed in observation holes.

iii) Permeability tests on strata through which the ground water is flowing.

It is desirable that investigations for seepage flows may have to be repeated during execution, particularly at the stage of formation cut, when it may be possible to make a closer examination to locate the seepage areas more accurately. The additional observations may warrant changes in the original design or the need for special measures.

13.6.16. Surface Run-Off

Surface run-off includes precipitation on the highway itself and flow from the adjoining areas. Run-off is ultimately led away from the highway area to the natural drainage channels by means of side drains. For the design of these drains, the following investigations, would need to be carried out:

1. study of ground contours of the land adjacent to the highway for determining the catchment contributing to the flow in side drains.

2. Determination of the surface characteristics of catchment area i.e., the type of soil, vegetation, slopes etc., and

3. Study of ground contours for locating the outfall points.

13.7. DETAILED PROJECT REPORT

The project data collected during the survey and investigations together with the estimates be worked out and presented for full appreciation by the appropriate authority. These should be prepared in the following three parts:

1. Estimate
2. Drawings
3. Report

13.7.1. Estimates

The project estimate should give the financial implications of the project. The estimate should include all the items of execution from site clearance to finishing activities of the work. The estimate should include general abstract of cost and detailed estimate. The quantity of each item should be carefully worked out and expressed with the relevant units. The rates should be based on the schedule of rates applicable for the district. Wherever the rates are worked out, detailed analysis should be included in the estimates.

13.7.2 Drawings

The following drawings are usually prepared:

1. Key map
2. Index map
3. Preliminary survey plan
4. Detailed plan and longitudinal section
5. Detailed cross- section
6. Land acquisition plans
7. Detailed drawings of CD works
8. Drawings of protection works and other structures
9. Quarry chart

The cross section drawings should be extended at least up to the proposed right of way.

13.7.3. Project Report

The Project Report is one of the most important parts of the project document and should give a precise amount of the different features for easy understanding and appreciation of the proposals. The information provided may be conveniently dealt with under the following heads:

1. Executive summary
2. Introduction
3. Socio-economic profile
4. Traffic surveys including traffic forecasts
5. Engineering surveys and investigations, and proposed road features
6. Pavement studies
7. Design standards and specification
8. Drainage facilities including cross-drainage structures
9. Materials, labour and equipment
10. Rates and cost estimates
11. Economic analysis and financial analysis
12. Construction constraints and programme
13. Miscellaneous
14. Conclusions and Recommendations

SPECIFICATIONS AND CODE OF PRACTICE

Specifications explain the nature and the type of work, materials to be used in the work, workmanship etc., and are very important for the execution of any work or a project. The specifications and codes of practice laid down by Indian Roads Congress, and Bureau of Indian Standards are required to be followed in construction of roads. The list of all relevant standards and codes of practice is given below.

I. INDIAN ROAD CONGRESS PUBLICATIONS

Sl. No.	Code / Document No.	Title
1.	IRC:2-1968	Route Marker Signs for National Highways (First Revision)
2.	IRC:3-1983	Dimensions & Weights of Road Design Vehicles (First Revision)
3.	IRC:5-1998	Standard Specifications and Code of Practice for Road Bridges, Section I – General Features of Design (Seventh Revision)
4.	IRC:6-2000	Standard Specifications and Code of Practice for Road Bridges, Section II – Loads and Stresses (Fourth Revision)
5.	IRC:7-1971	Recommended Practice for Numbering Bridges and Culverts (First Revision)
6.	IRC:8-1980	Type Designs for Highway Kilometre Stones (Second Revision)
7.	IRC:9-1972	Traffic Census on Non-Urban Roads (First Revision)
8.	IRC:10-1961	Recommended Practice for Borrowpits for Road Embankments Constructed by Manual Operation
9.	IRC:11-1962	Recommended Practice for the Design and Layout of Cycle Tracks
10.	IRC:12-1983	Recommended Practice for Location and Layout of Roadside Motor-Fuel Filling and Motor-Fuel Filling-cum-Service Stations (Second Revision)
11.	IRC:14-2004	Recommended Practice for Open Graded Premix Carpets (Third Revision)
12.	IRC:15-2002	Standard Specifications and Code of Practice for Construction of Concrete Roads (Third Revision)
13.	IRC:16-1989	Specification for Priming of Base Course with Bituminous Primers (First Revision)
14.	IRC:17-1965	Tentative Specification for Single Coat Bituminous Surface Dressing
15.	IRC:18-2000	Design Criteria for Prestressed Concrete Road Bridges (Post-Tensioned Concrete) (Third Revision)
16.	IRC:19-2005	Standard Specification and Code of Practice for Water Bound Macadam (Third Revision)
17.	IRC:20-1966	Recommended Practice for Bituminous Penetration Macadam (Full Grout)
18.	IRC:21-2000	Standard Specifications and Code of Practice for Road Bridges, Section III – Cement Concrete (Plain and Reinforced) (Third Revision)
19.	IRC:22-1986	Standard Specifications and Code of Practice for Road Bridges, Section VI – Composite Construction (First Revision)
20.	IRC:23-1966	Tentative Specification for Two Coat Bituminous Surface Dressing
21.	IRC:24-2001	Standard Specifications and Code of Practice for Road Bridges, Section V – Steel Road Bridges (Second Revision)
22.	IRC:25-1967	Type Designs for Boundary Stones
23	IRC:26-1967	Type Design for 200-Metre Stones
24.	IRC:27-1967	Tentative Specifications for Bituminous Macadam (Base & Binder Course)
25.	IRC:28-1967	Tentative Specifications for the Construction of Stabilised Soil Roads with Soft Aggregate in Areas of Moderate and High Rainfall

Sl. No.	Code / Document No.	Title
26.	IRC:29-1988	Specification for Bituminous Concrete (Asphaltic Concrete) for Road Pavement (First Revision)
27.	IRC:30-1968	Standard Letters and Numerals of Different Heights for Use on Highway Signs
28.	IRC:31-1969	Route Marker Signs for State Routes
29.	IRC:32-1969	Standard for Vertical and Horizontal Clearances of Overhead Electric Power and Telecommunication Lines as Related to Roads
30.	IRC:33-1969	Standard Procedure for Evaluation and Condition Surveys of Stabilised Soil Roads
31.	IRC:34-1970	Recommendations for Road Construction in Waterlogged Areas
32.	IRC:35-1997	Code of Practice for Road Markings (First Revision)
33.	IRC:36-1970	Recommended Practice for Construction of Earth Embankments for Road Works
34.	IRC:37-2001	Guidelines for the Design of Flexible Pavements (Second Revision)
35.	IRC:38-1988	Guidelines for Design of Horizontal Curves for Highways and Design Tables (First Revision)
36.	IRC:39-1986	Standards for Road-Rail Level Crossings (First Revision)
37.	IRC:40-2002	Standard Specifications and Code of Practice for Road Bridges, Section IV - Brick, Stone and Block Masonry (Second Revision)
38.	IRC:41-1997	Guideline for Type Designs for Check Barriers (First Revision)
39.	IRC:42-1972	Proforma for Record of Test Values of Locally Available Pavement Construction Materials
40.	IRC:43-1972	Recommended Practice for Tools, Equipment and Appliances for Concrete Pavement Construction
41.	IRC:44-1976	Tentative Guidelines for Cement Concrete Mix Design for Pavements (for Non-Air Entrained and Continuously Graded Concrete) (First Revision)
42.	IRC:45-1972	Recommendations for Estimating the Resistance of Soil Below the Maximum Scour Level in the Design of Well Foundations of Bridges
43.	IRC:46-1972	A Policy on Roadside Advertisements (First Revision)
44.	IRC:47-1972	Tentative Specification for Built-up Spray Grout
45.	IRC:48-1972	Tentative Specification for Bituminous Surface Dressing Using Precoated Aggregates
46.	IRC:49-1973	Recommended Practice for the Pulverization of Black Cotton Soils for Lime Stabilisation
47.	IRC:50-1973	Recommended Design Criteria for the Use of Cement Modified Soil in Road Construction
48.	IRC:51-1992	Guidelines for the Use of Soil Lime Mixes in Road Construction (First Revision)
49.	IRC:52-2001	Recommendations About the Alignment Survey and Geometric Design of Hill Roads (Second Revision)
50.	IRC:53-1982	Road Accident Forms A-1 and 4 (First Revision)
51.	IRC:54-1974	Lateral and Vertical Clearances at Underpasses for Vehicular Traffic
52.	IRC:55-1974	Recommended Practice for Sand-Bitumen Base Courses

Sl. No.	Code / Document No.	Title
53.	IRC:56-1974	Recommended Practice for Treatment of Embankment Slopes for Erosion Control
54.	IRC:57-2006	Recommended Practice for Sealing of Joints in Concrete Pavements (First Revision)
55.	IRC:58-2002	Guidelines for the Design of Plain Jointed Rigid Pavements for Highways (Second Revision)
56.	IRC:59-1976	Tentative Guidelines for the Design of Gap Graded Cement Concrete Mixes for Road Pavements
57.	IRC:60-1976	Tentative Guidelines for the Use of Lime- Fly Ash Concrete as Pavement Base or Sub-Base
58.	IRC:61-1976	Tentative Guidelines for the Construction of Cement Concrete Pavements in Hot Weather
59.	IRC:62-1976	Guidelines for Control of Access of Highways
60.	IRC:63-1976	Tentative Guidelines for the Use of Low Grade Aggregates and Soil Aggregates Mixtures in Road Pavement Construction
61.	IRC:64-1990	Guidelines for Capacity of Roads in Rural Areas (First Revision)
62.	IRC:65-1976	Recommended Practice for Traffic Rotaries
63.	IRC:66-1976	Recommended Practice for Sight Distance on Rural Highways
64.	IRC:67-2001	Code of Practice for Road Signs (First Revision)
65.	IRC:68-1976	Tentative Guidelines on Cement-Fly Ash Concrete for Rigid Pavement Construction
66.	IRC:69-1977	Space Standards for Roads in Urban Areas
67.	IRC:70-1977	Guidelines on Regulation and Control of Mixed Traffic in Urban Areas
68.	IRC:71-1977	Recommended Practice for Preparation of Notations
69.	IRC:72-1978	Recommended Practice for Use and Upkeep of Equipment, Tools and Appliances for Bituminous Pavement Construction
70.	IRC:73-1980	Geometric Design Standards for Rural (Non-Urban) Highways
71.	IRC:74-1979	Tentative Guidelines for Lean-Cement Concrete and Lean-Cement Fly Ash Concrete as a Pavement Base or Sub-Base
72.	IRC:75-1979	Guidelines for the Design of High Embankments
73.	IRC:76-1979	Tentative Guidelines for Structural Strength Evaluation of Rigid Airfield Pavements
74.	IRC:77-1979	Tentative Guidelines for Repair of Concrete Pavements Using Synthetic Resins
75.	IRC:78-2000	Standard Specifications and Code of Practice for Road Bridges, Section VII - Foundations and Substructure (Second Revision)
76.	IRC:79-1981	Recommended Practice for Road Delineators
77.	IRC:80-1981	Type Designs for Pick-up Bus Stops on Rural (i.e., Non-Urban) Highways
78.	IRC:81-1997	Guidelines for Strengthening of Flexible Road Pavements Using Benkelman Beam Deflection Technique (First Revision)
79.	IRC:82-1982	Code of Practice for Maintenance of Bituminous Surfaces of Highways
80.	IRC:83-1999 (Part-I)	Standard Specifications and Code of Practice for Road Bridges, Section IX - Bearings, Part I : Metallic Bearings (First Revision)

Sl. No.	Code / Document No.	Title
81.	IRC:83-1987 (Part II)	Standard Specifications and Code of Practice for Road Bridges, Section IX - Bearings, Part II: Elastomeric Bearings
82.	IRC:83-2002 (Part III)	Standard Specifications and Code of Practice for Road Bridges, Section IX - Bearings, Part III: POT, POT-CUMPTFE, PIN and Metallic Guide Bearings
83.	IRC:84-1983	Code of Practice for Curing of Cement Concrete Pavements
84.	IRC:85-1983	Recommended Practice for Accelerated Strength Testing & Evaluation of Concrete for Road and Airfield Constructions
85.	IRC:86-1983	Geometric Design Standards for Urban Roads in Plains
86.	IRC:87-1984	Guidelines for the Design and Erection of Falsework for Road Bridges
87.	IRC:88-1984	Recommended Practice for Lime Flyash Stabilised Soil Base/ Sub-Base in Pavement Construction
88.	IRC:89-1997	Guidelines for Design and Construction of River Training & Control Works for Road Bridges (First Revision)
89.	IRC:90-1985	Guidelines of Selection, Operation and Maintenance of Bituminous Hot Mix Plant
90.	IRC:91-1985	Tentative Guidelines for Construction of Cement Concrete Pavements in Cold Weather
91.	IRC:92-1985	Guidelines for the Design of Interchanges in Urban Areas
92.	IRC:93-1985	Guidelines on Design and Installation of Road Traffic Signals
93.	IRC:94-1986	Specification for Dense Bituminous Macadam
94.	IRC:95-1987	Specification for Semi-Dense Bituminous Concrete
95.	IRC:96-1987	Tentative Specification for Two-Coat Surface Dressing Using Cationic Bitumen Emulsion
96.	IRC:97-1987	Tentative Specification for Two-Coat Surface Dressing Using Cationic Bitumen Emulsion
97.	IRC:98-1997	Guidelines on Accommodation of Utility Services on Roads in Urban Areas (First Revision)
98.	IRC:99-1988	Tentative Guidelines on the Provision of Speed Breakers for Control of Vehicular Speeds on Minor Roads
99.	IRC:100-1988	Tentative Specification for Single Coat Surface Dressing Using Cationic Bitumen Emulsion
100.	IRC:101-1988	Guidelines for Design of Continuously Reinforced Concrete Pavement with Elastic Joints
101.	IRC:102-1988	Traffic Studies for Planning Bypasses Around Towns
102.	IRC:103-1988	Guidelines for Pedestrian Facilities
103.	IRC:104-1988	Guidelines for Environmental Impact Assessment of Highway Projects
104.	IRC:105-1988	Tentative Specification for Bituminous Concrete (Asphaltic Concrete) for Airfield Pavements
105.	IRC:106-1990	Guidelines for Capacity of Urban Roads in Plain Areas
106.	IRC:107-1992	Tentative Specifications for Bitumen Mastic Wearing Courses
107.	IRC:108-1996	Guidelines for Traffic Prediction on Rural Highways
108.	IRC:109-1997	Guidelines for Wet Mix Macadam
109.	IRC:110-2005	Standard Specifications and Code of Practice for Design and Construction of Surface Dressing

II. IRC SPECIAL PUBLICATIONS

Sl. No.	Code / Document No.	Title
110.	IRC:SP:4-1966	Bridge Loading Round the World
111.	IRC:SP:11-1984	Handbook of Quality Control for Construction of Roads and Runways (Second Revision)
112.	IRC:SP:12-1973	Tentative Recommendations on the Provision of Parking Spaces for Urban Areas
113.	IRC:SP:13-2004	Guidelines for the Design of Small Bridges and Culverts (First Revision)
114.	IRC:SP:14-1973	A Manual for the Applications of the Critical Path Method to Highway Projects in India
115.	IRC:SP:15-1996	Ribbon Development Along Highways and Its Prevention
116.	IRC:SP:16-2004	Guidelines for Surface Evenness of Highway Pavements (First Revision)
117.	IRC:SP:17-1977	Recommendations About Overlays on Cement Concrete Pavements
118.	IRC:SP:18-1978	Manual for Highway Bridge Maintenance Inspection
119.	IRC:SP:19-2001	Manual for Survey, Investigation and Preparation of Road Projects (Second Revision)
120.	IRC:SP:20-2002	Rural Roads Manual
121.	IRC:SP:22-1980	Recommendation for the Sizes for each Type of Road Making Machinery to Cater to the General Demand of Road Works
122.	IRC:SP:23-1983	Vertical Curves for Highways
123.	IRC:SP:24-1984	Guidelines on the Choice and Planning of Appropriate Technology in Road Construction
124.	IRC:SP:25-1984	Gopi and his Road Roller-Guidelines on Maintenance of Road Rollers
125.	IRC:SP:26-1984	Report Containing Recommendations of IRC Regional Workshops on Rural Road Development (with Supplementary Notes)
126.	IRC:SP:27-1984	Report Containing Recommendations of IRC Regional Workshops on Highway Safety
127.	IRC:SP:28-1995	Road Transport and Energy (First Revision)
128.	IRC:SP:29-1994	Directory of Indgenous Manufacturers of Road/ Bridge Construction Machinery & Important Bridge Components (First Revision)
129.	IRC:SP:30-1993	Manual on Economic Evaluation of Highway Projects in India (First Revision)
130.	IRC:SP:31-1992	New Traffic Signs
131.	IRC:SP:32-1988	Road Safety for Children (5-12 Years old)
132.	IRC:SP:33-1989	Guidelines on Supplemental Measures for Design, Detailing & Durability of Important Bridge Structures
133	IRC:SP:34-1989	General Guidelines About the Equipment for Bituminous Surface Dressing
134.	IRC:SP:35-1990	Guidelines for Inspection and Maintenance of Bridges
135.	IRC:SP:36-1991	Guidelines on Format for IRC Standards
136.	IRC:SP:37-1991	Guidelines for Evaluation of Load Carrying Capacity of Bridges
137.	IRC:SP:38-1992	Manual for Road Investment Decision Model
138.	IRC:SP:39-1992	Guidelines on Bulk Bitumen Transportation & Storage Equipment
139.	IRC:SP:40-1993	Guidelines on Techniques for Strengthening and Rehabilitation of Bridges
140.	IRC:SP:41-1994	Guidelines on Design of At-Grade Intersections in Rural & Urban Areas

Sl. No.	Code / Document No.	Title
141.	IRC:SP:42-1994	Guidelines on Road Drainage
142.	IRC:SP:43-1994	Guidelines on Low-Cost Traffic Management Technique for Urban Areas
143.	IRC:SP:44-1996	Highway Safety Code
144.	IRC:SP:45-1996	Time Series Data on Road Transport Passenger and Freight Movement (1951-1991)
145.	IRC:SP:46-1997	Steel Fibre Reinforced Concrete for Pavements
146.	IRC:SP:47-1998	Guidelines on Quality Systems for Road Bridges (Plain, Reinforced, Prestressed and Composite Concrete)
147.	IRC:SP:48-1998	Hill Road Manual
148.	IRC:SP:49-1998	Guidelines for the Use of Dry Lean Concrete as Sub-base for Rigid Pavement
149.	IRC:SP:50-1999	Guidelines on Urban Drainage
150.	IRC:SP:51-1999	Guidelines for Load Testing of Bridges
151.	IRC:SP:52-1999	Bridge Inspector's Reference Manual
152.	IRC:SP:53-2002	Guidelines on Use of Polymer and Rubber Modified Bitumen in Road Construction (First Revision)
153.	IRC:SP:54-2000	Project Preparation Manual for Bridges
154.	IRC:SP:55-2001	Guidelines for Safety in Construction Zones
155.	IRC:SP:56-2000	Guidelines for Steel Pedestrian Bridges
156.	IRC:SP:57-2000	Guidelines for Quality Systems for Road Construction
157.	IRC:SP:58-2001	Guidelines for Use of Flyash in Road Embankments
158.	IRC:SP:59-2002	Guidelines for Use of Geotextiles in Road Pavements and Associated Works
159.	IRC:SP:60-2002	An Approach Document for Assessment of Remaining Life of Concrete Bridges
160.	IRC:SP:61-2004	An Approach Document on Whole Life Costing for Bridges in India
161.	IRC:SP:62-2004	Guidelines for the Design and Construction of Cement Concrete Pavement for Rural Roads
162.	IRC:SP:63-2004	Guidelines for the Use of Interlocking Concrete Block Pavement
163.	IRC:SP:64-2005	Guidelines for the Analysis and Design of Cast-in-Place Voided Slab Superstructure
164.	IRC:SP:65-2005	Guidelines for Design and Construction of Segmental Bridges
165.	IRC:SP:66-2005	Guidelines for Design of Continuous Bridges
166.	IRC:SP:67-2005	Guidelines for Use of External and Unbonded Prestressing Tendons in Bridge Structures
167.	IRC:SP:68-2005	Guidelines for Construction of Roller Compacted Concrete Pavements
168.	IRC:SP:69-2005	Guidelines & Specifications for Expansion Joints
169.	IRC:SP:70-2005	Guidelines for the Use of High Performance Concrete in Bridges
170.	IRC:SP:71-2006	Guidelines for Design and Construction of Pretensioned Girder of Bridges
171.	IRC:SP:72-2007	Guidelines for the Design of Flexible Pavements for Low Volume Rural Roads
172.	IRC:SP:73-2007	Manual of Standards & Specifications for Two Laning of State Highways on B.O.T. Basis

REFERENCES :

1) IRC SP : 20 - 2002, Rural Roads Manual

2) IRC SP : 72 - 2007, Guidelines for the Design of Flexible Pavement for Rural Roads

3) MoRD - Specifications for Rural Roads, 2008

4) IRC SP : 23 - 1983, Vertical Curves for Highways

5) IRC 110 - 2005, Standard Specifications and Code of Practice for Design and Construction of Surface Dressing

6) IRC SP : 62 - 2004, Guidelines for the Design and Construction of Cement Concrete Pavement for Rural Roads

7) IRC:78-2000 Standard Specifications and Code of Practice for Road Bridges, Section VII - Foundations and Substructure (Second Revision)

8) IRC SP : 82 - 2008

9) IRC:73-1980 Geometric Design Standards for Rural (Non-Urban) Highways

10) IRC:38-1988 Guidelines for Design of Horizontal Curves for Highways and Design Tables (First Revision)

11) IRC : 13 - 2004,

12) RC:89-1997 Guidelines for Design and Construction of River Training & Control Works for Road Bridges (First Revision)

13) IRC:SP:54-2000 Project Preparation Manual for Bridges

14) MoRTH & Pocket Book for Bridge Engineers

15) IRC:5-1998 Standard Specifications and Code of Practice for Road Bridges, Section I – General Features of Design (Seventh Revision)

16) IRC:21-2000 Standard Specifications and Code of Practice for Road Bridges, Section III – Cement Concrete (Plain and Reinforced) (Third Revision)

17) IRC:6-2000 Standard Specifications and Code of Practice for Road Bridges, Section II – Loads and Stresses (Fourth Revision)

18) IRC:83-1999 Standard Specifications and Code of Practice for Road Bridges, (Part-I) Section IX - Bearings, Part I : Metallic Bearings (First Revision)

19) IRC:83-1987 Standard Specifications and Code of Practice for Road Bridges, (Part II) Section IX - Bearings, Part II: Elastomeric Bearings

20. Quality Control Handbook, NRRDA